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CIVIL ENGINEERING.

Construction of Chelsea Suspension Bridge.

From the London Builder, No. 1060.

At a recent meeting of the Society of Engineers Mr. Geo. Gordon Page read the following papers on this subject:—

The Chelsea Suspension Bridge, which has been opened to the public for the last five years, is a bridge remarkable in many respects; and which, in point of design, mode of construction, and economy of cost, presents features of great interest.

In the year 1846 an Act of Parliament was obtained, and the necessary funds granted for the construction of this bridge, which forms a communication between Pimlico, Belgravia, and Chelsea on one side of the river, and Battersea Park and the surrounding neighborhood on the other.

In addition to the design for the suspension bridge the engineer, Mr. Page, was instructed to prepare, for the consideration of the Metropolitan Improvement Commission, designs both for a bridge of seven arches, faced with stone, and one in cast iron of five arches; but, ultimately, the chief Commissioner of her Majesty's Works decided to carry into execution the suspension bridge originally mentioned in the Act. * * *

General Dimensions.—The length of the Chelsea Bridge is 704 feet from face to face of abutments; it consists of a centre opening

of 333 feet, with two side openings 166 feet 6 inches each. The piers are 88 feet long, and 19 feet wide, terminating in curved cut-waters; the piers are carried to a height of 7 feet 6 inches above high-water mark; the width of the bridge is 47 feet; the roadway at the centre of the bridge is 24 feet 6 inches above high water, and has a curve of 18 inches rise, commencing at the abutments. The towers and ornamental castings are of cast iron. The girders and flooring of the platform are of wrought iron.

Of the Abutments.—Too much attention cannot be bestowed on the abutments of a suspension bridge, as on their careful consideration and construction so much depends.

The abutment is the mass of masonry, or in some cases of natural rock, to which the extreme ends of the chains are made fast, and by the weight of which the strain from the chains is resisted.

The principles of the stability of the abutment of a suspension bridge are the same as those of the abutment of an arched bridge, but reversed. In the former there is a tendency to upset or slide forward instead of backward, as is the case in the latter. The weight or gravity of the abutment should always be sufficient to prevent it from sliding on its base, and its form and dimensions should be sufficient to prevent it from upsetting. The tendency to sliding forward may be considerably lessened by making the base of the abutment, or a portion of it, slope so as to be at right angles, or nearly so, to the resultant of pressure.

Of all parts of a suspension bridge the abutments are the last in which solidity and stability should be sacrificed to motives of economy.

The weight of the abutment should be equal to resisting twice the utmost strain that can be brought upon the chains by dead weight; and the total power of resistance, combining the weight and the tendency of the abutment to slide from the ground on which it stands, should be at least equal to four times the utmost strain that can be brought upon it.

The resistance offered by the adhesion of the abutment to the ground on which it stands, depends entirely upon the nature of that ground, and cannot by any general rule be accurately pre-determined.

When piles are used in the foundation they should be driven at an angle approaching as near as possible to the direction of the resultant of pressure.

With regard to the saddles on the abutment, by the aid of which the direction of the chains is changed, it is not always necessary to place rollers under them; but, as they must be capable of sliding to a sufficient extent, other means are sometimes resorted to in bridges of short span, and the saddles are sometimes laid on a bed of asphalted felt. In large suspension bridges rollers are, however, universally used, to allow for the expansion and contraction of a necessarily large extent of chain.

As it is most important that the chains or wire cables of a suspension bridge should be kept free from rust, the tunnels in the abutment through which the chains pass down to their fastenings are generally

constructed of such dimensions as will allow of space for access for the purposes of examination and repair if required

The abutments of the Chelsea Bridge consist of a mass of brickwork and concrete, measuring at the base 112 feet in length by 56 feet broad, and at the top 100 feet by 46 feet, and 40 feet deep.

The face of the abutment adjoining the river is composed of cast iron piles and plates, somewhat similar to those of the pier, with the exception that the iron work is not brought above the level of low water.

The portion of the abutment on which the land saddles and cradles bear, for changing the direction of the chains, rests upon timber piles, 14 inches square, driven deep into the bed of the river, and are from 3 feet 2 inches to 4 feet from centre to centre. These piles are cut off at the level of low water, 16 feet below Trinity high-water mark, and the spaces between filled up with hydraulic concrete. The cast iron and timber piles are tied together with wrought iron ties, 3 inches by $\frac{1}{2}$ inch. On the top is bedded a series of landings, forming a table at the level of low water 53 feet 6 inches by 27 feet 6 inches, upon which a mass of brickwork is erected up to a mean level of 3 feet below the level of the roadway. Upon this 12-inch landings are bedded for the reception of the cradles which carry the saddles on rollers. The cradles are bedded in asphalted felt, and firmly secured by wrought iron holdingdown bolts, brought up through the masonry from below. An invert, springing from beneath each saddle, is built in the brickwork below, so as to distribute equally the pressure from the cradles over the whole area of the foundation.

The mooring chains are carried down tunnels to the moorings, the tunnel forming an angle of 155 degrees with a horizontal line. The chains are secured to massive cast iron mooring plates, resting against three courses of 12-inch landings, respectively 12 feet by 8 feet 9 ins., 16 feet by 12 feet 6 inches, and 20 feet by 16 feet 3 inches. The tunnels are contracted at the bottom by elliptical brick domes, thus affording a complete bearing for that portion of the landings at the end of the tunnel. These landings rest against a mass of brickwork, with inverts, to distribute the pressure over the whole area of the abutment. This mass of brickwork rests on a series of timber piles, driven at the angle of 65 degrees with a horizontal line; the tops of the piles coming up above the level of the concrete, struts, and ties, and having a good bond with the brickwork, by which means the tendency to slide is greatly diminished, the whole space between the masses of brickwork being filled up solid with concrete.

The Pier Foundations.—The construction of the foundations of the piers combines all the advantages of foundations on bearing piles, made by means of coffer-dams, without the expense and obstruction to the waterways which they involve, and which would have rendered their use at Westminster Bridge all but impracticable.

The foundations of the piers consist of timber-bearing piles, 14 ins. square, driven deep into the bed of the river at intervals of 3 feet over the whole area of the pier, varying in depth from 40 feet 6 inches to

25 feet below the level of low-water, according to the resistance offered by the bed of the river.

The face or external surface of the piers consists of a cast iron casing of piles and plates driven alternately. The main piles are 12 ins. in diameter and 27 feet long, with longitudinal grooves on each side for the reception of the plates. These piles are driven to a uniform depth of 25 feet below the level of low-water, and between them are driven cast iron plates or sheeting 7 feet 2 inches wide, so that the pier is entirely cased from the foundations to the top, which is 7 feet 6 inches above Trinity datum. The space inclosed by this casing is then dredged to the hard gravel above the clay, and filled in solid with concrete up to the level of the top of the timber piles. On this foundation a flooring of stone landings is bedded, and on this the cast iron plates, frames, &c., forming the base of the towers, are placed.

The portion of the caisson situate above low water is hollow, being so formed to avoid throwing useless weight on the foundation, and is merely lined with brickwork, strengthened by cross walls and iron ties.

The whole of the iron work below the water was covered when hot with a protecting coating of tar. The thickness of metal in the caisson is 1 inch.

Of the Towers.—The towers which support the chains are entirely independent of the ornamental cast iron casing surrounding them, and consists of a cast iron columnar framing strongly braced both horizontally and vertically, carried to a height of 57 feet above high water.

The columns are cast in pairs, and have a diameter of 10 inches, and thickness of metal 1 inch. They are arranged in clusters of fours, and the whole are connected with six horizontal frames, occurring at intervals. The columns are not vertical, but incline towards each other upwards from either side of the pier, the columnar framing being 13 feet 6 inches at the base, and 9 feet 9 inches at the top. In the direction of the piers the columns are 4 feet 3 inches apart, and rise parallel to each other. There are two towers on each pier, 32 feet from centre to centre. The pressure from the chains coming directly from their centre, each tower carries therefore one-fourth of the whole weight of the bridge, or about 375 tons, or about 670 tons when the bridge is completely loaded: the sectional area of the columns is 284 square inches, and there is, therefore, a pressure upon them when the bridge is loaded, of 2·36 tons per square inch of section. The weight of the towers, exclusive of the ornamental cast iron casing, is 350 tons.

On the towers are fixed massive cast iron cradles upon which the saddles rest.

Of the Platform and Roadway.—The roadway platform is carried by two longitudinal trellis girders, running the whole length of the bridge from abutment to abutment, immediately beneath the chains, by which they are supported at intervals of 8 feet. These girders are suspended from the chains by wrought iron rods 2 inches in diameter.

The weight of the roadway is distributed over the whole of the four chains by the coupling plates to which the rods are attached; the rods

are jointed at the chains and at the roadway to accommodate any lateral motion that may occur, and are provided with screw coupling-boxes for their adjustment; the suspension rods pass through the longitudinal trellis girders, and support them from beneath.

The transverse girders which support the roadway are placed 8 feet apart from centre to centre, immediately under the suspension rods, and bear upon the bottom flanch of the longitudinal girders; are 31 ft. 10 inches long, 2 feet 2¾ inches deep at the centre, and 1 foot 11 ins. at the ends, where they are connected by a system of riveting with cantilevers 7 feet long, which practically form a continuation of them, and serve to support the overhanging footpaths; the sectional area of the top and bottom flanches is 10 inches, and the vertical rib ¼ inch thick, stiffened with T iron.

The small roadway bearers between the transverse girders are from 3 feet 3 inches to 3 feet 10 inches apart, 8 feet long, and vary in depth from 1 foot 5¾ inches to 1 foot 9½ inches, to suit the cambered surface of the roadway.

The several girders that support the roadway thus form a series of rectangular cells, which are covered with arched plates of wrought iron, stiffened with angle iron.

The haunches of the plates are filled in with a light concrete, composed of cork and bitumen. Previous to laying the bitumen concrete, the plates and girders are coated with asphalte.

The roadway is paved with oak blocks, 6 inches by 3 inches by 4 inches, bedded in bitumen, and trams of timber, flush with the roadway, with wrought iron strips bolted down on the top for durability.

The preference was given to the cork and bitumen concrete as a bedding for the roadway blocks, on account of lightness compared with ordinary concrete. Concrete, moreover, in such a position, and in so thin a layer, is liable to crack, and become in time pulverized, and (then no better than loose gravel) liable to be deranged by passing traffic.

The footpaths are paved in the same way, only the blocks are of smaller dimensions. This pavement rests on planking placed on joists running longitudinally, resting on the cantilevers. The available breadth of the carriage-way is 29 feet, and footpaths 14 feet 4 inches.

The longitudinal trellis girder is 6 feet deep, and its flanches are composed of a top plate 10 inches by 1¼ inch, and two angle irons, 3½ inches by 3½ inch by ⅝ inch thick; the effective area of the top and bottom flanches is 12½ square inches.

This girder materially stiffens the roadway, and prevents, in a great degree, that undulation to which suspension bridges are liable.

The handrail is of wrought iron, secured to the cantilevers at every 8 feet by brackets. The ornamental bosses and stays for supporting the railing are of cast iron.

The Chains and Saddles.—The chains of the Chelsea bridge are four in number, two being placed on either side, at a distance apart of 32 feet. They consist of links of seven and eight bars alternately,

8 inches wide, and of lengths varying from 16·55 feet at the towers to 16 feet at the centre of the span, so as to admit of a uniform horizontal distance of 16 feet from centre to centre of the pin-holes of each link, and are connected by pins 4 inches in diameter. The aggregate section of the four chains at the towers is 230 square inches, and at the centre 217½ square inches. The span of the centre opening is 348 feet, and the deflection of the chain is 29 feet. The semi-span of the back chains is 183 feet, and the deflection 30 feet 6 inches. The length of the chain for the centre opening is 354 feet 5 inches, and the length of each of the back chains 186 feet. The mooring chains are placed at an angle of 25°, and are 95 feet long, and have an aggregate section of 235 square inches. The total weight of the chains is 340 tons. The chains are carried over the towers by means of saddles formed of No. 8, 1-inch wrought iron rectangular plates, 5 feet 8 inches long, and 2 feet 10 inches wide, placed at intervals of 1 inch apart, and bolted together by No. 10 bolts. The bottom edges of the plates are planed, and are let into a cast iron plate 4 inches thick, also planed on its top and bottom surface, and which moves on ten 6-inch diameter steeled rollers, working on the cast iron bed-plate fixed at the top of the towers. The chains are connected to the saddles in the same way as the links of the chains are connected together. At the abutments the chains are diverted down the tunnels by means of saddles of similar construction to those on the towers, based on cast iron cradles, and placed at right angles to the resultant of the strains.

For mooring the chains the following means were adopted :—As has been observed in the description of the abutments, the tunnels for the mooring-chains are closed at the bottom by elliptical-shaped brick domes, against which the York landings are placed at right angles to the angle of inclination of the mooring-chains. The chains pass through holes formed in the centre of the landings (the dimensions of the landings were stated in the description of the abutments). A brick semi-circular arch or invert springs from the outer face of the landings, and connects the two sets of landings of each abutment together, by which means the whole weight of the middle portion of the abutment, it will be seen, is made to resist the pull of the chains. The chains are secured by means of castings, 21 inches deep, abutting against the landings, and are divided, each into four compartments, rather more than 2 inches wide, through which the chain-bars (here put two and two together) pass, and are moored by keys driven through the heads of the bars, and bearing against the mooring castings. Keys were here used instead of pins, to allow of an adjustment in the length of the chains. Similar means for adjusting the lengths of the chains were made at the saddles on the towers, but were not needed.

In calculating the length for the chains the curve may be assumed to represent a parabola, though, strickly speaking, the curve of the chains is peculiar to the construction ; but, deduction being made for the stretch due to the tension caused by the appended weight, the weight so deducted will be found practically correct. Care should be

taken to ascertain the exact distance of the span, as a small error in the horizontal distance will cause a serious error in the amount of deflection. It is well to provide for any discrepancy of this kind by leaving the centre links of the chains the last to be rolled; when, the error being known, it can be rectified without any serious interference with the rest of the construction.

For the erection of the chains four temporary chains were thrown across, made of 2-inch round bar-iron, and placed one on each side of the line of the chain to be erected. Upon these temporary chains traveling purchases worked, by which the bridge chains were hoisted and put in place. Four other and similar chains were thrown across beneath the former mentioned ones, to which timber platforms were suspended, and which served to carry the bars of the chains until the connexion of the links were complete. In the hope that the description may be acceptable, a few observations are subjoined respecting the manufacture of the bars.

The bars for the chains of the Chelsea Bridge were manufactured by the process patented by Messrs. Howard & Ravenhill, by which the head and body of the bars are rolled of one piece, and was affected as follows:—Piles, or, as they are technically called, balls of cleansed scrap iron, of about ¾ cwt. each, were heated (eighteen balls being the usual charge) in a reverberatory furnace of ordinary construction, and afterwards hammered into slabs about 2 inches thick by a 4-ton wrought iron hammer. The slabs, while still hot, were then piled in sets, of the weight required for the respective bars, and again heated and hammered into oblong masses of iron called shingle, somewhat wider than the width for the bars, and about 2 feet 9 inches long. The time required for heating the balls of scrap was one hour and a quarter; that is, so much time elapsed from the time of charging the furnace to the withdrawal of the first ball; and the time required for hammering the eighteen balls into slabs was three-quarters of an hour. It may therefore be observed, that the last ball withdrawn was nearly twice as long in the furnace as the first ball was; and it may, consequently, be supposed that some of the balls of scrap were too much and others too little heated; but the precautions adopted in the management of the furnace prevent any great irregularity in this respect. The balls first withdrawn were placed nearest the furnace; and, as withdrawn the remaining balls were pushed nearer the furnace, or otherwise, as their state required. The time for hammering a pile of slabs into shingle was about five minutes. By the two heats of hammerings the loss of iron was about 13 per cent.; and after the shingle was rolled into bars the total loss of iron was 20 per cent.; that is, the bar weighed one-fifth less than the scrap iron weighed from which it was manufactured. For converting the shingle into bars of the required form the shingle was heated to the required temperature in the furnace of the rolling-mills, and was then passed longitudinally through rollers till reduced to a width of 8 inches, and to a thickness of 2¾ inches. It was then transferred to other rollers, and passed through sideways; these rollers being so constructed as to act only on the extremities of the

bar, which, by this means, are spread out to the width required for the heads. The bar was then passed again longitudinally through ordinary rollers, till reduced to the length and thickness required; after which, while still hot, it was straightened by being beaten with wooden mallets. The time required for rolling a shingle into a bar was eight minutes.

The next process was boring the pin-holes. In doing this the bars composing each link were placed one on another, and bored by one operation, by which means uniformity of length was obtained. Shearing the heads of the bars to the proper form was the next operation. To do this the bars were fixed eccentrically on a table revolving in contact with shears, which, as the table turned, cut off the superfluous portions of the heads.

Every bar of the chains at this stage was tested with a strain of $13\frac{1}{2}$ tons per square inch; the contract requiring, in order to insure material of the best quality, that the iron used should stand this strain without a permanent elongation of more than one-fortieth of an inch in a ten-feet length; it having been found from experiments made that up to this strain the best commercial iron did not extend more than the very best iron that could be manufactured. It may be observed, that notwithstanding this amount of strain very few of the bars had to be rejected.

The last process in the manufacture of the chains was numbering the bars and lettering the links, that there should be no mistake in erecting the chains, as to every bar being in its proper place. A few words will suffice to explain how this was carried out. The chains were divided into eight portions, and named A, B, C, D, E, F, G, H, respectively. The chain A extended from the moorings on one side to the centre of the bridge, where it was joined by the chain B, which continued to the moorings on the other side, and so of the other three remaining chains. The heads of every bar of every link were then stamped with the letter of the chain to which it belonged, and numbered; the heads of the first links at the moorings being numbered 0, and the heads at the other extremity of these links 1. The heads of the second series of links were numbered 1 and 2; of the third series 2 and 3; and so on throughout the whole length of the chains. The bars of every link was also numbered 1, 2, 3, 4, 5, 6, 7, 8, showing the position they occupied in the link during the operation of boring.

The engineer considered it highly advantageous to the successful completion of this part of the bridge that the chains were prepared by Messrs. Howard, Ravenhill & Co., who spared no pains and no expense to carry out his instructions to produce a perfect structure; and so far from their making any attempt to evade any condition of the contract for their own advantage, the perfection of the work was their chief consideration.

It will show the excellence of the iron they produced to state that whereas the late Mr. Barlow deduced that the stretch of iron was at the rate of one-ten-thousandth part of its length for each ton, the iron which Messrs. Howard, Ravenhill & Co. produced for the chains of

the bridge only stretched from one-fifteen-thousandth to one-fourteen-thousandth part of the length per ton, being above fifty per cent. less than Mr. Barlow's.

As so much depends upon an honorable contractor in the execution of a work, Mr. Page authorized me to make these observations in justice to Messrs. Howard, Ravenhill & Co.

Of the Probable Load.—Before considering the degree of strain to which the chains are liable, it would be well to investigate the amount of load to which a bridge may be subjected.

M. Navier, a great authority on suspension bridges, calculated the load likely to occur on a bridge at 42 lbs. per square foot. The standard proof for suspension bridges in France is 200 kilogrammes per square metre, which amounts to 41 pounds per square foot, the proof load required by the French Government.

For troops on march, 21 inches in rank and 30 inches in pace are allowed, giving 4·37 superficial feet per man; which, at 11 stone each, would be 35¼ lbs. per square foot.

The load taken in the calculations for the Menai Bridge was 43 lbs. per square foot super.

An experiment was made by the engineer of the Chelsea Bridge, by packing picked men on a weigh bridge, with a result of 84 lbs. per superficial foot; but it is not within the limits of probability that such a crowd could accumulate on any bridge.

Seventy pounds per square foot of platform are assured as a standard for the load that may come on a bridge; as being the utmost load that the platform could hold; supposing it, in fact, quite filled with people crowded as close together as they could be. This, it is true, is not often likely to happen; but it may do so on a public occasion; and needs, therefore, to be provided for.

The march of cavalry, or the passage of cattle, is not so productive of dangerous effects as troops on the march, inasmuch as cavalry take up more room in proportion to their weight, and do not preserve a uniform pace.

As regards the greatest moving load or crowd, it is an acknowledged fact that it is impossible for a body of people on the move to occupy per man less space than trained troops; and as I have before shown that troops on the march do not produce a greater dead weight than 35¼ lbs. one may safely assume that the dead weight due to a moving crowd will not amount to so much.

Of the Strain on the Chains.—Having described the various loads that may come upon a bridge, it may be useful to show the strain produced on the chains of the Chelsea bridge under the several circumstances.

The strain on the chains from their weight alone is $1\frac{1}{10}$ ton. The strain from the weight of the platform and road alone is 3·32 tons, giving a total strain produced by the structure alone of 4·42 tons or 9·08 tons below the proof strain.

The strain on the chains from the weight of the structure and a load of 70 lbs. (being the weight per square foot of a dense crowd)

is 7·60 tons—or 5·9, nearly 6 tons, below the proof strain; so that the chains will carry in addition to the weight of the structure nearly three times the greatest crowd that can come upon the bridge, before the proof strain is arrived at. Taking the breaking strain of the chains at 28 tons, we should require seven and a-half times the greatest possible load to be brought on the bridge to produce that strain.

Before concluding these observations on the Chelsea bridge it may be interesting, without taking into consideration the high quality of the iron, to compare the strain on the chains with other suspension bridges; and for this purpose I may refer to the Hammersmith and Pesth bridges as fine examples of bridge engineering; both being built by the same engineer, Mr. Tiernery Clarke, at distant intervals; the Hammersmith bridge having been open thirty-six years, and the Pesth fourteen years.

The Hammersmith bridge is 710 feet 8 inches between abutments, the span of the main opening is 442 feet 6 inches, the deflection is 29 feet 6 inches, the useful width of platform is 30 feet, the sectional area of the chains is 180 square inches, the weight of a square foot of road 63 lbs., and the strain per sectional inch upon the chains from a load of 70 lbs., is 8·86 tons: the chains were proved up to 9 tons, leaving a margin of 14 tons between the proof strain and the strain from the greatest load.

The Pesth bridge is 1262 feet, between abutments, the central span is 666 feet; the deflection of the chains is 47 feet 6 inches, or $\frac{1}{14}$th of the span; the available width of roadway is 36 feet 3 inches; the weight of a square foot of suspended roadway is 74 lbs., and the chains have a sectional area of 510 square inches.

The strain produced on the chains with a load of 70 lbs. per square foot is 7·72 tons, or 1·28 tons below the proof strain, all the bars having been proved up to 9 tons.

The margin or allowance between the strain from the greatest load and the proof strain is therefore as follows:—

Hammersmith Bridge, ...	·14 tons.
Pesth Bridge, ...	1·28 "
Chelsea Bridge, ...	5·9 "

On the Construction of Wrought Iron Lattice Girders.

By Thomas Cargill, C. E.

From the Lond. Civ. Eng. and Arch. Journal, Dec., 1862.

(Continued from page 11.)

Before proceeding further with the practical part of the subject, I propose to make some remarks on the formulæ in general use, for calculating the horizontal strain in a girder; and to endeavor to investigate them in a manner which, without departing from recognised principles, may render them of more easy application in the designing of structures similar to those of which I am treating. The first formula to which our attention is directed, is that which gives us the great-

est horizontal strain at the centre of a girder under a uniformly distributed load, in which

$$S = \frac{W\,L}{8\,D} \quad . \quad . \quad . \quad . \quad (1)$$

W being the total load uniformly distributed, L the span, and D the depth between the centres of gravity of the top and bottom booms. Putting w for the constant load or weight of girder and portion of superstructure, and w_1 for the maximum variable load, we have $W = (w + w_1)$. We may consider the value of w_1 to be fixed, and always equal to one ton per lineal foot for every line of rails on the bridge; and confining our attention to one girder, we have $w_1 = L$. In bridges of moderate spans, that is, within the limits of 150 feet, it has been found by engineers sufficiently accurate and safe, in practice to take the constant weight of a bridge = 1 ton per foot run, which gives us, in the present instance, $w = \frac{w_1}{2} = \frac{L}{2}$. Substituting these values in equation (1) we have

$$S = \frac{\left(\frac{L}{2} + L\right)L}{8\,D} = \frac{3\,L^2}{16\,D} \quad . \quad . \quad . \quad (2)$$

The value for w is rather in excess of the actual weight in girders of small spans, but on the supposition that the weight of a bridge acts in direct opposition to the momentum of a moving load, it will be found an advantage rather than otherwise. That this opinion is entertained is shown by the fact that more than the necessary quantity of ballast is often heaped on bridges of small spans, for the express purpose of making them heavier. Taking D = one-twelfth of the span and putting this value in equation (2) and reducing, we find for the simplest equation for the maximum horizontal strain at centre

Fig. 1.

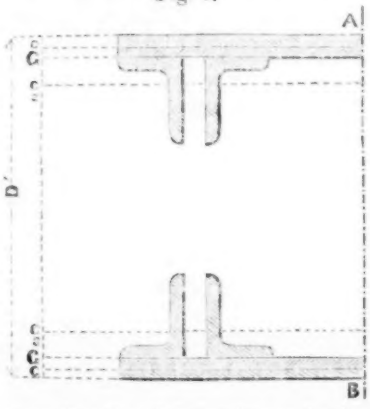


Fig. 1*a*.

$$S = 2{\cdot}25 \times L \quad . \quad . \quad . \quad (3)$$

This value for D agrees with that for the centre span of the Boyne Viaduct, in which S = 264 feet, and D = 22 feet 5 inches; the exact ratio is as 1 to 11·7, but as 22 feet 6 inches represents the depth from out to out, it would be reduced to about 6 inches less, by taking it to the centre of gravity of the booms, which would thus give $D = \frac{L}{12}$.

In all girders having discontinuous webs, the depth is capable of a greater variation with a limited increase of strain, than those of the continuous web form; the effects of the depth will be better seen when treating on the strains on the web.

In making calculations respecting the strength of girders, D is frequently taken as the total depth instead of the depth between the centres of gravity of the flanches; as it is necessary in some cases, and more correct in all, to adopt the latter value, we will proceed to determine it for a double lattice girder of a similar construction to that given in the number for October. [See July No. *Jour. Frank. Inst.*]

Let Fig. 1 represent the half section of the top and bottom flanches of the girder, the remaining half being precisely similar, the centres of gravity of each flanch will be somewhere in the line A B. It may be remarked that with their horizontal position, or position along the breadth of the flanches, we have nothing to do; it is their vertical position alone which affects the value of D in our equations. The simplest method of proceeding will be, to ascertain, first, the position of the centres of gravity of the top and bottom plates, and then that of the angle-irons, and to consider their weights as concentrated in those points, from which the position of the centres of gravity of the whole top and bottom flanches may be determined. In Fig. 1, let C C_1 be the vertical position of the centres of gravity of the top and bottom plates respectively, C_2 C_3 those of the angle-irons; the distance which is required to be found is G G_1, the available depth for calculation, answering to the value of D in the preceding equations. Make D_1 the total depth of the girder, as shown in the figure, and T_1 T_2 the sum of the thicknesses of the top and bottom plates, then, as the plates are supposed to be perfectly homogeneous,

$$C\,C_1 = D_1 - \left(\frac{T_1 + T_2}{2}\right)$$

In order to obtain the centres of gravity of the angle-irons, it will be only necessary to find that of one of them for each flanch. Let the angle-iron be imagined to be unrolled, or one of its flanches to be bent back into the position shown by the dotted lines in Fig. 1*a*, so that it shall assume the appearance of a straight piece of bar iron; if l_1 be the length of one of its flanches, l the length of the other, and t its thickness, its total length in the position shown will be $=(l_1+l-t)$, and the position of its centre of gravity from either end will be

$=\frac{(l_1+l-t)}{2}$; now supposing l to be the vertical flanch of the angle, and l the horizontal in Fig. 1, the distance of its centre of gravity or of the point C_2 from the under surface of the top plates will be

$$=l_1-\left(\frac{l_1+l-t}{2}\right)=\frac{l_1-l+t}{2};$$

similarly for the distance of C_3 from the interior surface of the bottom plates, for although the sum of the thicknesses of the top and bottom

plates may vary, yet the angle-irons both at top and bottom ought to be of the same scantling: we thus have the distance

$$C_2 C_3 = D_1 - [(T_1 + T_2) + (l_1 - l + t)].$$

The accurate position of all the points C, C_1, C_2, &c., will be in the line A B which divides the section into two similar halves, but for convenience sake I have placed them as shown in the figure. We may consider the force of gravity to act in vertical parallel lines, the resultant of which for the top plates passes through the point C, and for the angle-irons through C_2, and for the bottom flanches through C_1 and C_3, the distance $C C_2 =$

$$\frac{T_1}{2} + \left(\frac{l_1 - l + t}{2}\right) \text{ and } C_1 C_3 = \frac{T_2}{2} + \left(\frac{l_1 - l + t}{2}\right)$$

Our required distance $G G_1 = C C_1 - (C G + C_1 G_1)$.

Put A_1 for the area of the top plates, A_2 for that of the bottom ones, and a_1 for the area of the top or bottom angle-irons, then as the weight per unit of both plates and angle-irons is equal, in order to find C G we have the following proportion:—

$$C G : (C C_2 - C G) :: a_1 : A_1$$

$$\text{and } C G = \frac{C C_2 \times a_1}{(A_1 + a_1)}$$

$$\text{also for the bottom flanch, } C_1 G_1 = \frac{C_1 C_3 \times a_1}{(A_2 + a_1)}$$

If both the flanches be equal to one another, then $C G = C_1 G_1$, and $G G_1 = C C_1 - 2 C G$; in this case $C C_2 = C_1 C_3$, and finally, as $T_1 = T_2$, we obtain for $G G_1$ by substitution in the above equations

$$G G_1 = D_1 - T_1 - \left(T_1 + (l_1 - l + t) \times \frac{a_1}{A_1 + a_1}\right)$$

If b be the breadth of the plates $A_1 = b T_1$ and $a_1 = 4 (l_1 + l - t) t$; and applying the formula to an example, let $D_1 = 60''$, $T_1 = 1''$, $b = 24''$, and angle-irons $= 4'' \times 3'' \times \frac{1}{2}''$; then $A_1 = 24$ square inches, and $a_1 = 13$ square inches: and the available depth for calculation will be equal to

$$G G_1 = D = 59'' - \left(2{\cdot}50 \times \frac{13}{37}\right) = 58{\cdot}12''.$$

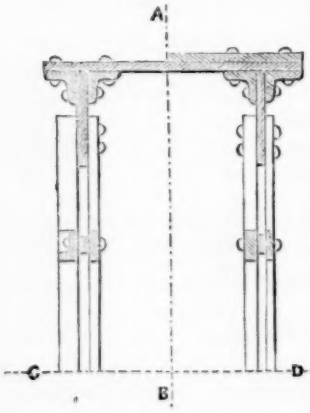
In girders of a less span than 40 feet, it would not be necessary to make this allowance, but it would be quite sufficiently accurate to take the total depth and calculate from it.

In treating of the duty of the angle-irons in the number for October, [July,] it was remarked that there was no advantage to be gained by employing angle-irons with their vertical flanches of a length very much exceeding the horizontal ones. Apart from the considerations there mentioned, it will be now evident that the result of the vertical portion of the boom is to lower the centre of gravity of the whole boom, and so reduce the depth required for calculation. In the above investigation I have taken no notice of the rivet holes; a_1 and A_1 are the gross areas, because, except where the strength is concerned, the

holes may be considered to be completely filled by the insertion of the rivets.

That the consideration of the correct value for D materially affects the shape which should be given to the booms of girders, will be seen from the inspection of an ordinary form shown in Fig. 2, in which the web, instead of being riveted directly to the angle-irons, is attached to vertical plates which are riveted in between the angle-irons; these vertical plates must at least be half an inch thick, in order to effectually take the strains of the struts and ties which are brought upon them, not continuously, but *per saltum*, as is the case in every lattice girder; consequently their area will bear a very large proportion to, and very probably exceed that of, the horizontal plates, and thus produce an injurious effect by considerably diminishing the value of D, which, as shown by the above investigation, is, *cæteris paribus*, inversely proportional to the area of the vertical portion of the flanches.

Fig. 2.



It will be seen on examining the section in Figure 2, that the area of the vertical plates cannot be included in the calculation of the area of the flanches, insomuch as they form no actual portion of them, but are merely a prolongation of the web. Their sectional areas being useless, they can only be regarded in the light of stiffening pieces to the booms; as they are four in number (two only are shown in the half section in fig. 2), and as they are continued throughout the whole length of the girder, an estimate of their weight would show that this advantage is obtained at too great a sacrifice of material, and addition to the dead weight of the girder; their own weight also acts in a most disadvantageous manner, and adds to the side strain on the horizontal plates, and although they may tend to somewhat stiffen the entire booms, they have a contrary effect on the plates considered independently, for they increase their liability to buckling.

It would be well here to draw a distinction between the meaning of the terms "booms" and "flanches;" the booms always include the flanches, but the flanches may or may not include the booms; the flanches, together with any stiffening or packing pieces applied to them, constitute the booms, but it must be borne in mind that it is the area of the former alone which can be included in computing the strength of the girder. Fig. 1 is an example of the simplest form of flanch for a double lattice girder, the whole of the area of which might be used as the gross area for determining its strength.

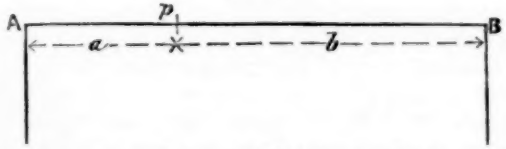
Where this mode of imparting stiffness to the boom is adopted, (see Fig. 2) it would be preferable to increase the length of the vertical flanches of the angle-irons; this method is open to the objections al-

ready urged against it, but we should on the other hand obtain the value of the sectional area of the stiffening pieces, which we do not where the vertical plates are employed. The use of the vertical plates causes twice as much riveting in the webs than what is required in the other arrangement, where the web is attached directly to the angle-irons.

To return to the horizontal strains. The case of the strain resulting from the effect of a weight at the centre offers but little interest, except in the deflecting and testing of girders, so we pass on to a consideration of the general formula for the horizontal strain on any part of the boom of a girder, produced by a uniformly distributed load.

In Fig. 3, let A B represent one of the booms of a girder, it is required to find the strain at a point P, which divides A B into segments a and b. The uniform load in the present instance, will consist of two

Fig. 3.



portions—the constant, and the variable load, which equal respectively w and w_1. The total load $w + w_1$ produces an upward reaction at

$A = \frac{w + w_1}{2}$, and the moment of this force to cause fracture at

$p = \frac{w + w_1}{2} \times a$. Let S = horizontal strain, D = depth of girder, and let m = weight of segment a; then the forces acting in opposition

$$= S \times D + m \times \frac{a}{2}, \text{ from which}$$

$$S = \frac{w + w_1}{2\,D} \times a - m \times \frac{a}{2} = \frac{a}{2}\left(\frac{w + w_1 - m}{D}\right)$$

But $m = \frac{w + w_1}{a + b} \times a$, and putting this value in our equation

$$S = \frac{\frac{a}{2}\left((w + w_1) - \frac{(w + w_1)}{a + b}\,a\right)}{D}$$

Making $w + w_1 = W$, we have

$$S = \frac{a}{2\,D}\left(\frac{W(a + b) - W a}{a + b}\right) = \frac{W \times a\,b}{2\,D(a + b)} \quad . \quad . \quad (4)$$

The limits for the value of a and b are $a = o$, $b = L$, and $a = b = \frac{L}{2}$

in the former case $S = o$, and in the latter $S = \frac{WL}{8\,D}$. (1)

If in equation (4) we substitute the value before given for $W=\frac{3L}{2}$, we have $S=\frac{3ab\times(a+b)}{4D(a+b)}=\frac{3ab}{4D}$, and making $D=\frac{a+b}{12}$ we have for girders of this particular class

$$S=\frac{9ab}{L} \quad . \quad . \quad . \quad . \quad (5)$$

The two equations (1) and (4) supply sufficient data to calculate with ease and accuracy the strains on any part of the boom of a girder. In adopting $D=\frac{L}{12}$, I have been guided by the best examples existing of lattice girders—which are unfortunately but too few—and also, that in a large number which have come under my personal observation and direction, I have found this ratio is either actually obtained, or very closely approximated to. The facilities it offers for calculation have been already shown.

The next point to be considered is the quantity of material required, or what the sectional area of the flanches should be in order to resist a strain acting at any point *p*. This depends altogether upon the amount of strain we wish to impose upon any square inch of iron. Widely different opinions have been, and are still, entertained upon this point, but without wasting time, and encumbering valuable space with attempts to judge between their relative merits, I shall assume that the safe working strain is equal to one-fifth of the ultimate tensile strain of the material. The tensile strength of plates may be taken at 22 tons per square inch; this is about two tons higher than it is usually considered at, but the demand for iron of a better quality than what was formerly employed in bridges has led to the manufacture of iron of a superior description. Any one may be convinced of this fact by perusing the specifications respecting the quality and tests of the iron to be used in our large railway bridges for India;* the bar iron is specified to be able to resist a tensile strain of 24 and even 26 tons, and it is evident that such a requisition could only be founded on the fact that a much better class of iron is now turned out of the workshops than when 20 tons per square inch was the highest standard of efficiency. We shall thus have $\frac{22}{5}=4{\cdot}4$, or $4\frac{1}{2}$ tons for our working strain on iron in a state of tension. In apportioning the strength of the flanches it must be kept in mind that the top flanch is in compression, and the bottom in tension, and that iron is weaker in compression with respect to tension, as 11 : 12; and consequently making A = the section required for the bottom boom, and A_1 for the top, $A_1=\frac{12A}{11}$. The effect of the rivet holes in the top and bottom flanches must be also taken into account. If in the top flanch, which is under compression, the rivet holes were completely filled up by the inserted rivets, their effect might be disregarded; that this is the case, where steam riveting is employed, will be shown hereafter; therefore,

* See Mr. Humber's last work, 'A Complete Treatise on Cast and Wrought Iron Bridge Construction.'

reducing in the above proportion, we shall have the safe strain for iron in compression = 4 tons per square inch.

In order to avoid confusion by having two constants for the booms, and also to provide for the contingencies of hand-riveting, in which the holes are never filled entirely by the rivets, it will be more advantageous and safer to take the net area of the top boom at 4·5 tons, instead of the gross area at 4 tons, and thus make the calculations similar. If A = net area required in the bottom boom at any point, n = the number of rivets in the cross section of the flanch at that point (taking care not to make the section across a wrapper or covering plate placed over a joint), d = diameter of rivets, and t = thickness of plates; then the gross area $a = A + ndt$ and if a_1 = gross area of top boom,

$$a_1 = \frac{12}{11} A + ndt.$$

Let A = area required at centre of boom, then

$$A = \frac{S}{p} = \frac{WL}{8D \times p}, \text{ making } p = 4{\cdot}5 \text{ tons},$$

and substituting the values assumed above, we have for the area at the

$$\text{centre } A = \frac{L}{2} \quad . \quad . \quad . \quad . \quad (6)$$

and for the area at any other point where a . b are the segments into which the span is divided,

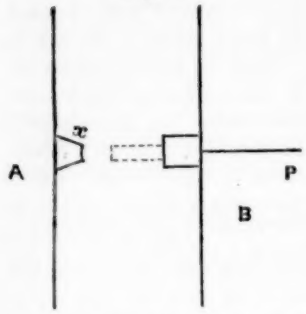
$$A = \frac{2ab}{L} \quad . \quad . \quad . \quad (7)$$

In small bridges the top and bottom flanches may be made equal to one another in area, but where the proper proportion is observed, A must be reduced or increased accordingly.

Before passing on to the strains on the web, which constitutes the essential difference between this and other form of girders, it may not be out of place to make a few remarks respecting steam and hand-riveting. If the heads of rivets which have been inserted in a plate by hand-riveting be cut off, the rivets themselves may be knocked out of the plate by a hammer; but the rivets which have been put in by the machine cannot be so displaced, the only means of removing them is by either punching or drilling them out, which is equivalent to reboring the solid plate; if a piece of plate be examined which has been sheared across the rivets, it will be observed that, if the rivets were put in by the machine, they appear to have become completely incorporated with the plate itself, and to form a part of it. The flanches are the only portions of a double lattice girder to which steam-riveting can be applied. This will be manifest from an inspection of Fig. 4, which is a diagram representing the main features of a steam-riveting machine; it consists of two principal parts, A and B; A is the portion which forms the resistance, and the projection on its surface takes the place of the sledge which is held by one man in hand-riveting

against the head of the rivet, while P is the hammer, worked by a small cylinder and piston-rod, which gives the blow, and in so doing is brought into the position shown by the dotted lines. It is clear that any portions of a girder which are required to be united by riveting, must be able to be brought into the space shown by *x* in the figure, and which does not admit of any very great variation, although capable of adjustment within certain limits. In constructing the girder in the work-shops, the angle-irons and plates are put together by temporary bolts, and a few rivets driven by hand, and then the whole boom is slung up on a cross beam traversing the length of the work-shop, and passed in succession backwards and forwards through the spaces *x* of the machine, until the whole of the rivets are inserted. A single lattice or plate girder may be riveted together completely by the machine. One of the great difficulties to be overcome in hand-riveting cannot possibly occur where the machine is employed—viz: the difficulty of bringing the two heads of the rivet exactly opposite; in hand-riveting they are frequently not so, that is, the longitudinal axis of the rivet does not pass through the centre of both heads, and the consequence is that the head is not concentric round the rivet hole and the bearing surface, or the force which draws the plates together is not equal on both sides of the plates. If the bearing surface were very unequally distributed around the rivet hole, it is evident that if a sudden shock came upon the rivet it would start, and be drawn through the hole. Another advantage of the machine is that it altogether dispenses with the preliminary hammering of the plates in vicinity of the rivet hole, and which has often in thin plates injuriously affected their strength by producing a distortion or wind in them.

Fig. 4.



We shall next consider the strains on the compression and tension bars composing the web; and also notice the forms best suited to the different strains brought upon them.

(To be Continued.)

Prevention of Decay in Timber for Shipbuilding and other Purposes.

From the Journal of the Society of Arts, No. 519.

(Continued from page 16.)

II.—*Preservation of Store or Yard Timber and its Preliminary Artificial Seasoning for Working Purposes.*

It is well known that the trunks of trees grow by the superposition of annual concentric layers, and consequently are composed of wood of very different ages. For example, an oak of 150 years encloses in its centre and at its foot wood of the same age, and at the surface and top wood of a year old. Arrived at a certain age—but varying

exceedingly in quality according to climate, exposure, and soil—vegetation ceases, and the oldest layers begin to ferment and decompose. We become aware of this when we see the topmost branches of the tree prematurely lose their leaves, or when they remain without foliage in the spring. Then we say the tree is withering, or on the decline. That is an immediate blemish, and the branches which are touched with it are liable to perish in the centre, even before they are brought into use. When, however, this defect is not very apparent, it will not be necessary to exaggerate the danger; and those even slightly acquainted with the laws of the resistance of solids very well know that the central portion of a piece of timber bears a very little part in the resistance of the log, as regards either fracture or tension. But it is not prudent to allow trees to attain that limit beyond which the vital principle begins to decay.

Timber, sound at the heart and exempt from all accidental and local defects, only decays under the influence of certain causes, which it is important carefully to define, in order that we may be enabled to combat them successfully. When a tree is felled it encloses in its fibres as well as in its capillary channels a considerable quantity of sap, which is nothing else but water charged with gummy, saccharine, saline, mucilaginous, and albuminous matters. In this state the latter are very liable to ferment, but they lose this liability when, by the evaporation of the sap, they pass to a dry and solid state; so that the first suggestion which naturally presents itself to the mind, is to subject the timber to a lengthened seasoning.

Unfortunately timber in general, and particularly that of the oak species, requires a very long time before the mass is thoroughly seasoned. This arises partly because (the wood being inaccessible to heat) the sap, excepting that immediately below the surface, does not exude in vapor—the only form in which it could escape quickly—and partly from the incrustation and the narrowness of the channels, which present a more or less powerful obstacle to the evaporation of these exhalations.

A natural seasoning would be sufficient for specimens of moderate thickness, such as boards for inlaying and paneling, &c., &c., or even for some thicker woods, from which in working up they take off only a thin shaving from the surface—for example, the planking of ships; but it would be entirely useless as regards rough square logs intended to be used as ribs, and from which from 40 to 50 per cent. of the original mass is taken off. Then, however seasoned the exterior may appear, a considerable degree of dampness is found under the fibrous tissue of the wood. Exposure of the timber to free air for some length of time can alone remedy this evil; and, as I before stated, such was the course pursued with all ships formerly built, when left to season on the stocks for 10, 15, and even 20 years.

Now that circumstances oblige us to forego this excellent plan, it is imperative to replace it by artificial and speedy methods. They consist

1st.—In depriving the timber of the greatest possible quantity of sap, and consequently of the fermenting principles therein contained.

2d. In subjecting felled and sawn timber, before putting together, to an artificial seasoning.

3d. In charring or scorching the surface of the wood by means of a slight carbonization when the work is finished.

It is a well known fact that the longer wood has remained under water, the more rapidly it dries; for instance, in Paris, every one is aware that the firewood brought out of the river is less green and burns better than that brought by wagon or boat. In reflecting on the cause of a phenomenon apparently so paradoxical, this conviction is forced upon us, that it is of the same nature (or from the same cause) as that which causes the "Endosmose" and "Exosmose" discovered and described by the celebrated naturalist, Dutrochet.

When timber is submerged, the sap, by reason of the matters which it holds in solution, is denser than the pure water; moreover, it is enclosed in fibres or channels permeable at the side. The phenomenon of Endosmose ought therefore to be gradually produced, and to extend itself, as by a kind of cementation; so that, in supposing the surrounding water to be flowing, or at least changing, this water will conclude by occupying, if not altogether, at least in a great degree, the place of the sap, which will have issued forth, carrying with it the fermenting principles with which it is charged. The timber, therefore, which has remained sufficiently long in the water ought to be much less susceptible of fermentation than that seasoned only by the atmosphere. Besides, as pure water evaporates much easier than that which contains certain principles, this timber ought to be seasoned much sooner than the other—a fact confirmed by long experience.

If the preceding explanations are well founded, we should conclude from them that the Endosmose will develop itself with so much greater rapidity, as there shall be a greater difference of density between the surrounding fluid and the sap. On the contrary, the denser the liquid in which the timber is immersed, so much longer will the Endosmose be retarded, and, if there is any difference between the specific gravities of the sap and the water, Endosmose will not be produced.

This remark is most important, as it proves that timber cannot be seasoned in salt water, but in fresh, or at the most, in brackish water. As to the sea, it can only be regarded as an economical storeyard. The submersion of building timber becomes now so much the more necessary, as floating is very seldom resorted to, the greater part of the timber being brought to the ports by railway.*

With regard to the question, "How long it will be necessary to allow the timber to remain in water in order that it may get rid as much as possible of its sap?" the author recommends:—One year in river water, two years in fresh water (frequently changed), and three years in brackish water (which should be always changed). At the close of these several periods, the boards intended for planking should be taken out to be put in store; or they might be left to season them-

* In particular, preliminary immersion is indispensable for Guayana timber; which, as the produce of a country warm and damp in the extreme—and where vegetation never stops—we may really say never—contains a prodigious quantity of sap. To the neglect of this precaution we must, without doubt, attribute the unfortunate results appearing in some timber brought from that country and worked up in the French dock-yards thirty years ago.

selves naturally for two years, at least, before being worked up. As to the rough timber for ribs, seasoning in store would be, as already stated, totally insufficient; and it would be requisite after shaping, but before putting together, to subject it to an artificial seasoning. There have been many plans of this description in use for some time in France and England, but they have only been applied to wood of moderate thickness, such as boards, flooring, and wainscoting.

The plan adopted in London is the injection, by means of a ventilator, of hot air into the drying stove where the wood is placed; by this the temperature is gently and gradually raised until it reaches boiling heat. But, as wood is one of the worst conductors known of caloric, if this plan is applied to large logs, the interior fibres still retain their original bulk, while those near the surface have a tendency to shrink, the consequence of which would be cracks and splits of more or less depth. If, however, this defect is not too apparent, it would have little influence on timber used as ribs, but would render it unfit for planking.

Another method in operation at this present time at Tourlaville near Cherbourg, for which the inventor, M. Guibert, has taken out a patent, appears, in the author's opinion, to give at once more expeditious and sure results than those obtained from the use of dry and hot air. It consists in filling the drying stove with smoke produced by the distillation of certain combustible matters, such as saw-dust, waste tan, and smith's coal, &c. By means of a ventilator, ingeniously arranged, a rotary movement round the logs laid to season is given to the smoke, so as to obtain an average uniform temperature in every part. By this plan, as the distillation of combustibles is always attended with a considerable discharge of steam, all cracks and splits appear to be prevented.

The apparatus invented for the same purpose by Messrs. Lège and Fleury Pironnet, for the injection of sulphate of copper into beech and poplar, may likewise be used. This apparatus is composed of a cylinder 15 or 16 mètres (or from 49 to 52 feet) in length, with an opening of about two mètres (or 6½ feet), into which, after the wood is placed and the opening hermetically sealed, a jet of steam is introduced, intended at first to enter the timber and open its pores for the purpose of obtaining a sudden vacuum, so as to establish at any time a communication between the interior of the cylinder and the cold water condenser, like Watt's condenser, at the same time that the air-pump is put in action. The vacuum caused is very powerful, equal to an altitude of 65 centimetres, or 25½ ins. of the barometer. Under the double influence of the heat of the vacuum, the sap is quickly evaporated from the wood as steam, and ejected from the cylinder by the air-pump, so that in a very short time the wood is fully prepared to admit the preserving liquid through the entire bulk. If the wood is only required to be seasoned, a current of warm air is substituted for the liquid, and to this a certain proportion of sulphuric acid should, in the author's opinion, be added. Without doubt, this method of seasoning would be the quickest, and we should thereby avoid the cracks

and splinters which are nearly always produced when dry and hot air only is applied.

The principal drawbacks to the use of the apparatus are its complicated details and heavy cost, but the result to be obtained is most important.

(To be Continued.)

Testing Iron Railway Bridges in Prussia.

From the Lond. Practical Mechanic's Journal, June, 1863.

In the German periodical, "Leitch f. Bauwesen," 1862, we notice an interesting article on the different regulations for testing railway bridges, and the question is raised whether it is safe to assume a maximum strain of 10,000 lbs. (about 5 tons Eng.) as in France only 8200 lbs. are reckoned. The answer is in the affirmative. From the experiments made on the deflection of girders of different constructions, it is found that the same depends wholly on the proportions of each construction. Calling the central deflection f, the span, l, modulus of elasticity, E, the height between the centres of top and bottom flanches, h, the strain on the flanches, k, the weight of the structure itself, p, and the maximum load per foot run, p_1 while p_2 = a similar but smaller load, P = the maximum load in the centre, and P_1 = a smaller central load; then we have for smaller bridges,

$$\frac{P_1 l_2}{6 P E k} k.$$

For large bridges, the following formulæ are to be used, when—

$$A = \frac{p^2 l^2 k}{(p + p_1) E h}$$

For parabolical girders, $f = \left(\cdot 3456 + \frac{h^2}{l^2} \right) A.$

For lattice girders of same section throughout,

$$f = \left(\cdot 2083 + \frac{h}{4 l} \right) A.$$

For lattice girders of varying sectional area,

$$f + \left(\cdot 25 + \frac{h}{2 l} \right) A.$$

For a pair of girders loaded on one bay,

$$f = \left(\cdot 146\, a + \frac{h}{3 l} \right) A.$$

where A signifies the relative proportion between the largest and smallest sectional area of the flanches.

MECHANICS, PHYSICS, AND CHEMISTRY.

International Exhibition, 1862.—*Jurors' Report.*

From the Lond. Civ. Eng. and Arch. Jour., Nov., 1862.

CLASS VIII.—MACHINERY IN GENERAL. *Subdivision I. Prime Movers.*

SECTION I.—*Boilers, Furnaces, &c.*—With a few exceptions, the actual boilers exhibited (as distinguished from drawings and models) belong to traction engines, or to portable or semi-portable steam engines; and those boilers are marked on the whole by efforts made with greater or less success to economize space, and to facilitate cleansing and repairs by means of improved arrangements of the heating surface, or otherwise. The following examples may be cited:—Bray's traction engine (United Kingdom—1805), Ransomes and Sims' portable steam engine (United Kingdom—1961), J. Taylor and Co.'s traction engine (United Kingdom—2004), Tuxford and Son's engines (United Kingdom—2195), J. F. Cail and Co.'s engine (France—1144), Farcot and Son's condensing steam engine France—1152), Hediard's boiler (France—1131), Laurens and Thomas' boiler (France—1151), Zambeaux's portable boiler (France—1137), Albaret and Co.'s portable steam engine (France—1207), Henschel and Son's boiler tubes (Hesse-Cassel—434).

Many of the boilers are provided with the means of superheating steam, either by passing it through tubes in the smoke-box, or by enclosing the steam chest in a smoke box or flue.

In the engine exhibited by Mr. Wenham (United Kingdom—2019), the steam, after having performed part of its work in a smaller or high pressure cylinder, is supplied with heat while in the act of expanding during its passage from the cylinder to the larger or low pressure cylinder. This application of heat to steam is at once sound in principle and successful in practice.

The most new and unusual in form of the boilers exhibited, is that by Mr. Harrison (United Kingdom—1877), which is an American invention. It consists of a number of hollow cast iron globes, all equal and similar, connected with each other through cylindrical necks or short tubes, the whole being bound together, in a rectangular arrangement, with wrought iron bolts. A boiler of any required size can at once be made by building and bolting together the proper number of globes and necks. The water and steam are inside, the fire outside.

M. Grimaldi (Italy—1001) exhibits a cylindrical boiler, containing either flues or tubes for the flame, and turning slowly about a horizontal axis, so as to bring every part of the surface in contact with the liquid water and with the steam alternately, in order to increase the efficiency of the surface in raising steam, and prevent over-heating and corrosion.

The boilers shown by Mr. H. Cater (United Kingdom—1814), (presenting a peculiar arrangement of tubes,) although they were set up too late to be the subject of an award, may here be mentioned, as be-

ing at work in the boiler-yard of the western annexe, with satisfactory results.

The following articles fall especially under the head of furnaces and their appendages:—

An apparatus for promoting perfect combustion and preventing smoke, by using very small jets of steam to blow streams of air into the furnace, is exhibited by Mr. D. K. Clarke (United Kingdom—1822). Its practical success has been well established. It is at work in the boiler-yard.

Siegburg's improved grate (Prussia—1320), and Schulz, Knaudt and Co.'s fire-box (Prussia—1318).

In M. Hubazy's portable engine (Austria—569) the furnace is adapted for the burning of straw, a most useful contrivance where other fuel is scarce.

The apparatus of M. Steenstrup (Norway—213) is intended for the prevention of rust in boilers. The exhibitor takes advantage of the chemical affinity of chloride of calcium for water, so as to dry completely the rust already formed, which consequently falls to powder and detaches itself from the boiler.

The "Hydratmo-Purificateur," or water-softening apparatus, exhibited by M. Durenne (France—1163), purifies water from salts of lime by the aid of its property of depositing such salts when raised to a high temperature. A rectangular case contains, one above another, a series of horizontal trays or platforms, heated by means of the waste steam of the engine, which enters at the bottom of the case, and slowly ascends. The water to be purified is introduced at the top, and trickles from tray to tray, becoming heated by the condensation of the steam, and depositing parts of its salts of lime on each tray, until it is discharged at the bottom of the apparatus, completely softened, and at a high temperature; so that the heat of the steam employed is not wasted. By opening the front of the case the trays are taken out, from time to time, and cleansed. The practical working of this apparatus is most efficient.

Mr. Siemens' regenerative furnace (United Kingdom—1987) is well known through descriptions which have appeared in the Transactions of the Institution of Mechanical Engineers, and the Reports of the British Association for the Advancement of Science.

Section II.—*Land Steam Engine.*—Of the land steam engines, some are fixed, or semi-fixed, some portable, and some are road locomotives, or "traction engines."

Among the fixed and semi-fixed engines, although a few good examples of beam-engines and vertical-engines are to be found, the horizontal construction generally prevails; probably owing to the ease and convenience with which all parts are accessible. In some cases, as in the machinery of Messrs. Manlove, Alliott, & Co. (United Kingdom—1924) and Messrs. Whitmore & Son (United Kingdom—2023), a horizontal engine is used to drive a vertical shaft directly, which is a good arrangement for corn-mills and centrifugal machines.

Many of the steam engines are employed to drive machinery be-

longing properly to other classes; and in such cases it is the steam engine alone that falls under the consideration of the Jury of Class VIII.

In other cases the steam engine drives some piece of mechanism, such as a hoist, a crane, a pump, a blowing-machine, &c., belonging to a different subdivision of Class VIII., and in such cases any explanation which may be required of the machinery so driven will be found in the proper subdivision of this report.

With respect to the steam engines in the present Exhibition, as compared with those of 1851, it may be observed that they show an increased employment of high pressure, great expansion and superheating, an increased use of surface condensation (generally effected by means of a great number of small horizontal tubes), a tendency towards simplicity in the framing and main moving parts, a general abandonment of devices that are more curious than useful, and a higher perfection of workmanship and finish; all of which improvements combine to produce greater economy of fuel, power, and repairs.

Setting aside merit of a kind that does not require special explanation, such as simplicity, good workmanship, practical success, &c., the following remarks may be made as to those engines which present new and useful features:—

Manlove, Alliott, & Co. (United Kingdom—1924) exhibit a pair of horizontal engines for working centrifugal machines, which are placed with their cylinders bottom to bottom on one frame; so that the tendency to strain the frame, which arises from the inertia of the moving parts, may be balanced by making the pistons move in opposite directions.

The double-cylinder expansive engine, in various modifications, is numerously represented. In the engine of Mr. Wenham (United Kingdom—2019) the steam is superheated in its passage from the small to the large cylinder (see Section I). In Messrs. May & Co.'s engine (United Kingdom—1927) the dead-points are done away with by placing the cranks of the large and small cylinders at right angles to each other; the steam being exhausted from the small cylinder into a wrought iron reservoir, jacketed with high pressure steam from the boiler.

In one of the engines exhibited by Carrett, Marshall and Co., (United Kingdom—1813) the dead-point is passed (though its effect is not wholly done away with) by placing the cranks of the small and large cylinders not directly opposite each other, but at a very obtuse angle. (This arrangement has also been employed in Craddock's engine.) The opposite, or nearly opposite motion of the large and small pistons is well known to be favorable to balance of inertia, and also to a good distribution of the same, by enabling it to pass in the most direct manner from either end of the small cylinder into the adjoining end of the large cylinder. In the drawing of M. Delandtsheer's engine (Belgium—265), the cranks for the large and small cylinders are exactly opposite in direction, and the dead-points are done away with

by combining a pair of engines with cranks at right angles to each other in the usual way.

The end-to-end double cylinder arrangement is exemplified in the engine of M. Scribe (Belgium—278), and in a model in the United Kingdom division, which is not numbered nor mentioned in the catalogue. [Exhibited by Mr. E. E. Allen.]

For producing variable expansion, the system most frequently employed is the ordinary link motion; and next in order as to frequency, the link motion with a separate expansion-valve driven by a third eccentric. In Messrs. Ferrabee's engine (United Kingdom—1852), the expansion-valve is driven by a straight-link motion of its own, worked by means of two eccentrics on a shaft, which is made to turn at double the speed of the engine shaft by means of a pair of toothed-wheels.

In many cases also, and especially in the foreign engines, the variable expansion is produced by means of the compound slide, regulated in some cases by hand, and in others by the governor; and amongst the latter class may be specified the engines of the Magdeburg-Hamburg Steam Navigation Company (Prussia—1312), the Sprottau Iron Works (Prussia—1321), Farcot and Co., (France—1152), C. T. Porter (United States—29). In Messrs. Farcot's engine, the action of the governor upon the variable expansion is very exact and perfect, owing mainly to the construction of the governor, in which, by a peculiar mode of suspension and counterpoise, there is obtained a sufficiently accurate practical approximation to the theoretic accuracy of the parabolic governor, but without its complexity and liability to derangement. (For details, see the report of M. Tresca to the Societé d'Encouragement pour l'Industrie Nationale, published in their Bulletin for 1861.) In the governor of Mr. Porter's engine a similar result is obtained by using light balls and a high speed with a heavy vertical load to balance the great centrifugal force. The figure and movement of the side-valve in this engine are of a peculiar kind, suited to open and close rapidly with a comparatively small travel.

The pumping-engines of Mr. Steele (United States—38), and of Mr. Worthington (United States—28) are remarkable as being engines of rapid stroke without fly-wheels. In the former there is a single cylinder, whose slide-valve is moved when the piston is at its dead-points, by an apparatus which is in fact equivalent to a small auxiliary steam cylinder. In the latter there are a pair of equal cylinders, working at half stroke behind each other, the slide-valve of each cylinder being shifted by the piston of the other.

In M. Scheutz's rotary steam engine (Sweden—273), the advantages of simplicity and compactness, which the rotary engine is admitted to possess, are combined with the power of working expansively in a very perfect manner; while at the same time the disadvantages of engines of that class are to a great extent overcome; for the pressures at the shaft are balanced, the sliding vanes or pistons are relieved of pressure while they are passing the stops; and the steam-tight bearings, when worn, can all be tightened at one operation, in consequence of the conical form of the casing.

The North Moor Iron Foundry (United Kingdom—1948) exhibit a steam turbine which has been found to work efficiently, and which is convenient for driving fans, the fan and turbine being fixed on the same shaft. M. Bourdon (France—1156) has a turbine driven by a current of water, which is itself driven by a steam jet.

Of the single-acting Cornish engine one example only appears, represented by the model of Messrs. Harvey and Co. (United Kingdom —1880).

The traction engines to which awards have been made by this Jury are those exhibited by Bray's Traction Engine Company (United Kingdom—1805), J. Taylor and Co. (United Kingdom—2004), Tuxford and Sons (United Kingdom—2195). It is well known that, although steam carriages for common roads are of old date, traction engines, or road locomotives, are of recent introduction. All the three engines above mentioned work well in practice.

Mr. Bray's is capable of acting as a portable steam engine, a steam crane, or a fire engine, at will; the rim of each of its two driving wheels is furnished with blades or spades, which can be pushed out or drawn in, according to the steepness of the road and state of its surface and the load to be drawn, so as to give just the required hold and no more. Messrs. Taylor's is marked by the merit of great simplicity. It has two driving wheels, six feet in diameter, without blades. Messrs. Tuxford's has a single roller instead of driving wheels; its engine is well protected against injury by dirt, and the engine driver and steersman are together.*

* Mr. Yarrow's steam carriage (United Kingdom—2033) was included in Class VIII. of the Catalogue, although its place would have more properly been in Class V. The Jury of Class VIII. examined it, and formed a very favorable opinion of its merit, so far as that could be ascertained by mere inspection. They were at first desirous of having its performance practically tested on some road near the Exhibition; but they were induced to desist from considering it further by the belief that it was about to be transferred to the class to which it properly belonged. Unfortunately that belief was erroneous; and the steam carriage in question has not been the subject of any award.

(To be Continued.)

Proceedings of the Association for the Prevention of Steam Boiler Explosions, Manchester.

From the Lond. Mechanics' Magazine, February, 1863.

This association has just issued its annual report. The report is so full of valuable information that we deem it advisable to give it to our readers almost extant. After some introductory observations on the character of the boilers examined, Mr. L. E. Fletcher, the chief engineer, says:—

Before entering upon the detailed consideration of the defects detected on the examinations, it may be stated that a gradual improvement is found to be going on in the general character of the boilers under inspection, as well as in the arrangements of their fittings. The new constructions are marked with more simplicity and accessibility of parts and fittings, and can be more readily attended to by the engineer in charge, as well as more satisfactorily examined by the inspector, and entail much less anxiety in answering for their safety.

Notwithstanding this general improvement, however, the defects ascertained this year are more numerous than those of last year; this may be accounted for by the increased number of "thorough" examinations previously referred to, which have revealed defects otherwise unknown; an additional illustration of their importance.

The defects discovered in boilers are mainly of two distinct classes —one relating to their construction, and the other to their condition.

Under the first head, namely, that of construction, 196 recommendations have been made, which are as follow:—

In 153 boilers the internal flue-tubes have been recommended to be strengthened by hooping.

In 18 boilers the shells have been recommended to be strengthened at the steam dome by stays of angle iron, &c.

In 9 boilers the shells have been recommended to be strengthened at the ends.

In 16 boilers the load on the safety-valves has been recommended to be reduced.

The following are those defects appertaining to the second head—namely, that of condition. Of these, 85, which are as follows, were considered dangerous:—fractures of plates and angle irons, 13; blistered plate, 1; furnaces out of shape, 12; corrosion, 37; defective safety-valves, 5; defective water-gauges, 9; defective feed apparatus, 1; defective blow-out apparatus, 7.

Others not actually dangerous, but still unsatisfactory, are as follows:—fracture, 60; blistered plates, 19; furnaces out of shape, 33; corrosion, 270; safety-valves irregularly loaded and otherwise out of order, 94; water-gauges out of order, 135; pressure-gauges out of order, 76; feed apparatus out of order, 35; blow-off apparatus out of order, 224; fusible plugs out of order, 49; also two instances of deficiency of water.

It may be added that many of the above defects were observed at visits made early in the year, and since that time many of them have been repaired.

To some of these defects more detailed reference may be made.

Fracture.—One of the most fruitful sources of fracture in boilers is the unequal expansion and contraction of their different parts, on account of the various temperatures, which are caused, in many cases, though not in all, by imperfect circulation of the water.

This has been kept in view so constantly in previous reports, that little more now is necessary than an enumeration of any additional facts, which have lately come under notice.

It may, therefore, briefly be stated that grooving still continues to manifest itself in double-flued boilers at the tube angle irons and end plates, more especially at the furnace mouth; and is more active in proportion as the end plates are rigidly stayed. In no class of boiler, however, is this action found to be so destructive as that in which the furnace tubes are brought so close together, that there is not room for the angle iron at either end of the flue to be carried completely round them; and is, therefore, supplemented by what is called a "saddle-

plate," which, with its complement of the two partial angle iron hoops, forms a "spectacle-piece." These "saddle-pieces" are found to groove so deeply that in some cases the whole thickness of the plate becomes eaten through. There is no satisfactory cure for this but their entire removal, and the tapering down of the flue-tubes at the mouth, so as to increase the intermediate space.

Channeling at the transverse seams at the bottom of the shell of internally fired boilers, is still met with. It generally is discovered in the bottom external flue, on the outside of the plate immediately at the edge of the overlap, being deepest at the centre or "keel" line, and dying out in about 15 inches on each side, but very frequently in much less. In one instance, however, it was found on the internal surface of the plate, and to be situated as high as the side wall on which the boiler was set.

On the whole, a gradual improvement, both with regard to channeling at the bottom seams, and grooving at the end plates and angle irons, is taking place in the boilers under inspection. This improvement is due, with regard to the former, to the more general adoption of means for heating the feed water, as well as to the boilers being now more frequently set, so that the heat from the furnace flues passes immediately under the bottom, and then lastly along the sides, by which means the circulation of the water is improved; while, with regard to the latter, the improvement is due to the fact of the end plates being now less rigidly stayed, and thus, as has been stated in previous reports, having room to "breathe."

Boilers with two furnaces running into a single oval flue, containing a number of vertical water tubes, have the advantage of a more rapid circulation of the water, which is decidedly calculated to prevent both transverse channeling at the ring seams and grooving at the angle irons. There are, however, but a small number of these boilers under inspection, in proportion to those of the double-flued class; but, as far as observation has been made, they certainly appear to compare favorably, on the above points, with their competitors. Water tubes have also been added in a few cases to ordinary double-flued boilers, being fixed behind the fire-bridge with a view to promote circulation, while, with the same object, a new boiler has lately been brought out, in which water pockets or midfeathers at varying angles are fixed in the flue-tube, with a view of securing it against collapse, and at the same time promoting circulation of the water.

Other cases of fracture have occurred from fixing angle iron strengthening hoops to flues in an improper manner. This has been so fully gone into in the printed abstract of the monthly report for June last, and which was circulated among the members, that nothing need now be added beyond stating that several additional cases have since been met with of plates at the crowns of furnace tubes becoming burnt and cracked, when the thimbles or ferrules between the plates and angle iron hoops, explained in the above report, have been omitted.

Other cases, again, of fracture, have been caused by the flue-tubes and shell being bound together by a cross stay in the middle of their

length, when, from the unequal expansion of the two, one has injured the other.

One case of fracture has been met with in an externally fired boiler, which occurred at one of the transverse seams of rivets, from the sudden cooling of the plates, by the too hasty introduction of a quantity of cold water immediately after blowing out; while very similar injury has arisen at the transverse seams over the furnaces in other externally fired boilers when in work, and, in addition, several of their plates have both bulged and blistered. Boilers externally heated by the flames passing off from iron furnaces have been found to be specially liable to start at the seams, and crack at the rivet holes, at the point where the flame impinges.

A boiler with two internal furnaces, as well as an external one beneath it, added with a view to promote circulation of the water, was found to bulge in the plate of the external shell over the fire, while the internal furnace tubes remained uninjured. It is thought that this boiler, from the fact of its combining within itself the two classes of firing, viz: internal and external, affords an apt opportunity of comparing the merits of the two systems, while the result just recorded is fully borne out, by a more extended observation of other boilers.

Blistered Plates.—This subject has been somewhat anticipated under the previous heading, and it will now, therefore, be only necessary to point out, that the fact of plates, by good makers, being liable to blister unawares, and which previous examination evidently fails to detect, shows the importance of not hazarding an explosion upon their soundness. Thus the strength of no unassisted plate, exposed to the action of the fire, should be relied on; and, consequently, it becomes most desirable that furnaces should, in every instance, be stayed either by flanched seams, or with hoops of angle iron, T-iron, or other advantageous form.

Furnaces Out of Shape.—The general causes of shortness of water, from which overheating and injury to the furnace crowns ensue, are found to be as follows:—

1. The direct neglect by the engine-tenter of the feed apparatus, which is too obvious to need remark, and too glaringly careless to be otherwise than exceptional.

2. False indication of the glass water-gauges.

3. Loss of water at night on account of leakage of the blow-out apparatus, sometimes from its being carelessly and imperfectly closed.

4. The lighting of fires by night watchmen, and others, without any water in the boiler.

5. Blowing the water out of the boiler with the fire still left in it.

An efficient low water safety-valve, which would—on the sinking of the water below its proper level—relieve the pressure of the steam, would evidently save the furnaces under some of the above circumstances, though not under all.

It should be added, that some furnaces are out of shape from their first construction, being found on actual measurement to be as much so as one or two inches, merely from careless workmanship, which

passes unobserved until detected on inspection. This inaccuracy considerably weakens the flues, especially when the major axis is horizontal, since the natural tendency of all furnace tubes is to collapse vertically.

Corrosion.—Corrosion is found to be going on in all boilers more or less, and it will be seen that the greatest number of dangerous defects in the preceding list are to be found under this head. A few instances may be given. In one case, a boiler set upon a mid-feather wall, 15 inches thick, had a channel eaten right along it about 8 inches wide, which ran down the centre of the seating, while the plate at the edges of the brickwork appeared quite sound, and the danger consequently passed for some time unsuspected. In a second instance, with a mid-feather 2 ft. wide, the plate was found to be eaten almost through from nearly one end of the boiler to the other; while in a third, where lime had been allowed to come in contact with the boiler at the mid-feather, the plate was completely pulverized, and could be carried away in handfuls. In a fourth case, a vertical tubular boiler had been placed close to a wall, one part being in actual contact. Damp in the brickwork set up corrosive action in the plate, which, being concealed by the position, went on undetected until the metal was completely eaten through, and a piece blown out by the pressure of the steam. The original plating of the boiler was thick, the pressure low, and the corrosive action local, only affecting a surface of about 12 ins. square, so that the rent did not extend.

A fruitful source of corrosion is found in the leakage of blow-out pipes at their attachment to the shell, while in some cases the pipes themselves are fractured, and continue so for some time unawares, the leakage meanwhile playing on the bottom plate, from which corrosion necessarily ensues.

Examples of corrosion might be multiplied indefinitely; enough, however, has been said to show the importance of having all parts of the boiler accessible to examination, the flues sufficiently capacious, and the seatings as narrow as possible, and also of having the brickwork removed occasionally, at all events in places, so as to ascertain the condition of the plates, since to conclude that the parts concealed are in the same condition as those in view, has been found in practice to be fallacious.

The examples of corrosion, previously referred to, have all been external, and caused in every case by moisture, arising either from leakage or damp in the flue. Internal corrosion is not generally so dangerous, and arises from acidity in the water. Many members are now using carbonate of soda, and all those who do so speak highly of it. Even the Manchester town's water is improved by the introduction of a slight quantity. This water is not found to be dangerously corrosive, but to speckle the plates over minute indentations, in some cases depositing small scales, like miniature flattened walnuts, about $\frac{3}{4}$-inch diameter and $\frac{1}{8}$-inch thick. These, on being severed from the plate, leave behind them shallow prints on its surface. One firm, having several 50-horse power boilers, and which are fed with Manchester

town's water, uses half a pound of soda in each per diem, and finds this quantity sufficient to neutralize the acidity.

Defective Safety-Valves.—Reckless or even careless overloading is now seldom if ever met with in the boilers under inspection, though some cases have come under notice of most defective arrangements in new boilers, the safety-valves being placed on the steam-pipes instead of directly on the shell, so that the communication between them was contingent upon the junction-valve being open.

Many safety-valves are found improperly loaded, that is, insecurely so, and with loose irregular weights. Importance is attached to safety-valve levers being loaded, with but a single suitably-adjusted weight at their end.

The attachment of internal loading to dead-weight safety-valves has, in some cases, been found most insecure. This is a point, from the concealment of the weights and links within the boiler, which is likely to escape attention, though serious scalding would ensue in a confined boiler-house in case of the valves suddenly breaking loose. Of internally loaded dead-weight valves, those are the safest which are boxed-in and fitted with a hand-lifting lever, and a discharge pipe for the waste steam.

(To be Continued.)

Ice Making Machine.

From the London Practical Mechanic's Journal, April, 1863.

One hundred years ago, the notion of making ice by a machine, would have seemed as preposterous as an attempt to call down fire from heaven; by the popular masses, even the most civilized in Europe, it would have been deemed an impossible but highly impious attempt to usurp or travestie the supposed special powers of Deity alone; but to the best informed, the ice making would have seemed *more* impracticable than even the calling down or diverting the lightnings of heaven. The latter had, in fact, been already done; Franklin had actually shown that the thunder cloud could be made obedient to such humble apparatus as a common kite, a wetted string, and a house door key, and its fire, by their means, directed where he willed. *Thermotics*, however, as Whewell has happily designated the whole doctrine of heat, were, as yet, almost unknown; the labors of Black and of many of his contemporaries and immediate successors were required before a clear perception of the facts of latent heat and the laws of vaporization, admitted of any one's discerning that cold making, or ice making machines, were possibilities. And yet, analogous operations, embracing nearly everything that theory demanded, though as yet hidden and unexplained, had been empyrically practised for ages. The Hindoo and the Arab, and after them the Spaniard, had cooled their water and their wine in porous earthen vessels by the evaporation of the film of the liquid, constantly transuded by the permeable clay, without a thought as to what was the *cause* of this mysterious property in the *Alcarazza*. For hundreds of years the Bengalee had filled and put forth his earthen saucers at sunset in the yet warm air, and exposed

them to the starry clearness of the tropic night sky, and without surprise, and equally without knowledge, had gathered his crop of thin *ice* at an early dawn from off their surfaces. Banks, Solander, Fordyce, Blagden, had found that the rapid evaporation of sweat from the skin would enable the temperature of the human body to be preserved almost constant, during an exposure for some time to a temperature that would boil beef.

Watt, arguing upon the discoveries of his friend Dr. Black, had clearly seen the amount of heat carried off by evaporation, or diminution vapor tension, and, in result, had devised the steam jacket to avoid the ill effects of these in his engine. It is highly probable that had Watt lived longer, and his penetrative and inventive mind been directed to the object, he would have accomplished an ice making machine. The experiments of Configliarchi and of Leslie, however, present the first true attempts, with adequate knowledge of principles, to produce cold making machines.

They showed that water, and even mercury could be frozen; the former by exposing it to evaporation, at common temperature in an air pump vacuum, provided with a large surface of strong sulphuric acid, to absorb the aqueous vapor and assist the pump in withdrawing it as fast as it was formed; the latter, by causing sulphuric ether, in a vessel surrounding the mercury, rapidly to boil off at its boiling point *in vacuo*. The high volatility of this liquid, which boils in the open air at about 95° Fah., greatly exalting the effects producible in the preceding case with water. Leslie found that many other substances might be used with advantage to withdraw the aqueous vapor instead of sulphuric acid, which, as it sucked up water, diminished in absorptive power and increased in bulk, and was always dangerous to handle; and having found that most highly dried and porous bodies answered well as absorbents, and more especially, pulverized clay, or trap rock, or oatmeal after torrefaction, he proposed this as a method of making ice upon a manufacturing scale, and devised a special form of air pump for the purpose, We may here notice that an ingenious proposal by Mr. J. Sked of Woolwich, for adaptation of Leslie's apparatus to ice making on board the Peninsular and Oriental Co. Steamship, in connexion with their engines, will be found in our correspondence this month. By the aid of sulphuric ether, and such absorbents, a reduction of temperature from 68° Fahrenheit down to 49° Fahrenheit was obtained. Much more recently, enormously greater reductions of temperature have been obtained by Thilorier, Faraday, and others, by means of the crystals of solidified carbonic acid, obtained either by its evolution under extreme pressure, or its condensation to a high degree, as by Thilorier's beautiful pumps. It is thus procured as a highly volatile liquid, which on being permitted to rush out at a small aperture, so falls in temperature as to become a snow of solid crystals. When these crystals are immersed in sulphuric ether, they dissolve, and, in analogy with the dissolving salts of the older "freezing mixtures," cool the ether itself. If the whole be kept beneath the air pump vacuum, rapid evaporation at this low temperature and extremely re-

duced tension go on so fast, that temperatures of — 150° Fahrenheit have been reached, and at which the absolute alcohol of the spirit thermometer becomes thick and viscid from approaching congelation.

Perhaps the most remarkable and elegant experiment, illustrative of the power of evaporation in carrying off heat, is that of *freezing water in a red hot crucible*, due originally, we believe, to M. Boutigny, and dependent in part upon the singular molecular condition of liquids in contact with heated surfaces, first observed, in 1797, by Liedenfrost, and which Boutigny, who has greatly extended our knowledge of the subject, has called the *spheroidal state*. Into a red hot platina crucible a little water is dropped, which, at once, assumes this state, and remains a round little rotating spheroid without sensibly evaporating, although the crucible is kept red hot over a lamp. A few drops of liquid sulphurous acid, a highly volatile fluid, and which mixes readily with water, is now dropped into the crucible; it flashes off into vapor instantly, carrying with it some of the vapor of the water suddenly brought down to its state and temperature of ordinary ebullition, and on rapidly inverting the still nearly red hot crucible, there drops out of it, a lump of ice. To one who has seen this, as we have had the advantage of seeing it, performed with the adroitness of such an experimenter as Boutigny, nothing can suggest more completely the notion of a miracle.

All these methods, however powerful some of them seem to be in the reduction of temperature, are affairs of the laboratory and lecture table; even Leslie's arrangements, to which it is understood a patient trial was given with a view to economize results, were found wholly unsuited to the manufacturing scale.

About twenty years ago, the first *cooling* machine, (not an ice machine,) as far as our knowledge goes, was proposed for the purpose of cooling the air, or even the drinks of hospitals in India.

In the very ancient and deep mine of Chemnitz in Saxony, existed a peculiar form of pumping engine, known as "the Chemnitz machine," of which Switzer, and other old authors on hydraulics, have given account.

An air vessel existed as part of this machine, within which the air was compressed by a column of many fathoms of water. When a small cock was opened in this air vessel, air rushed out with amazing force, carrying particles of the water with it, but the reduction of temperature within the issuing blast, produced by its sudden and enormous increase of volume, was such, that the watery particles were frozen, and fell as a shower of snow. This, as well as the converse fact of the great evolution of heat, when air is condensed into the reservoir of an air gun, had long been known, but no economic advantage had been taken of the former.

It was now proposed to sink deep in the earth, far below the range of annual change of its temperature in India, two large air reservoirs, like steam boilers of plate iron, to condense powerfully into one or other of these alternately, common atmospheric air by the aid of steam or other power, and after the heat, evolved by the condensation, had

been absorbed by the contact of this vessel with the ground, to permit the condensed air to expand and escape, either directly into the spaces intended to be cooled by it, or through tubes presenting large surfaces, or by other means, so as, indirectly, to cool air or liquids. The method, though at one time seriously entertained, was never, we believe, even tried by the Indian Government, who had obtained several reports from men of science on the subject. Here, however, are all the elements of a true cold making machine, and whose theory is very much the same as that of the two remarkable machines that have succeeded it, and which we are about to describe, viz: the Ether Ice Machine of Harrison and Siebe, and the Ammonia Ice Machine of M. Carré, both of which were exhibited in the western annexe at the Exhibition of last year, and probably were regarded by the million with more wonder, and we regret to say, with the same unsatisfied curiosity, with which the masses were left to regard so many unexplained objects there. The interest, indeed we may say the importance, attaching to these machines, as examples of a class, is far from ephemeral or exhausted; we feel assured that they are a class yet destined, not alone greatly to increase the luxuries and comforts of many, in every temperate and warm climate, but to prove the means by which the white race of mankind shall be enabled to pursue his great destiny of subduing and civilizing the torrid, and to him unhealthy regions of the globe, hitherto his grave, and the almost exclusive possession of lower races of mankind.

Fundamentally, every ice making machine in principle reposes upon the interconvertibility of *energy* and *heat*.

In all material substances, every change of volume, (usually accompanied by change of molecular state,) from greater to less, is attended with an evolution of heat, if from less to greater, with a disappearance of heat. The heat which disappears (and is usually taken from surrounding bodies,) in the latter case, which is that with which we are chiefly concerned here, is the exact equivalent of the forces, whether temporary or permanent, that are required to produce and maintain the new and increased volume; it becomes *latent*, for it lies hid then, in mechanical or chemical balanced forces. Every vaporizable liquid body may be expanded into vapor, under a constant pressure, by increase of temperature, or at a constant temperature by decrease of pressure, in either case absorbing as much sensible heat as is equivalent to the latent heat of the vapor.

Conversely the vapor may be again reduced to the liquid state, even at a higher temperature, by increase of pressure. The latent heat taken up by the vapor being now given out as sensible heat, which may, more or less, increase the temperature of the liquid produced, as it is or is not, shared with surrounding bodies. If the condensed liquid be surrounded by a *large* volume of another liquid at a constant temperature, as low, or somewhat lower, than the original temperature; the vaporizable liquids shall rapidly return to its original conditions in all respects, and the process may be repeated continually. Hence every ice machine reduces itself to three conditions of action—

1. The vaporization of the volatile fluid by reduction of pressure, by which heat is carried off from bodies in contact with it, to an extent the limit of which is the whole latent heat of the vapor. 2. The liquefaction of the vapor at a temperature which may be considerably higher by increase of pressure. 3. The dissipation of the heat now returned to the vapor liquid, by conduction or convection, or both, to a surrounding body. Thus, an ice machine is throughout strictly the converse of the steam engine. In the former, mechanical energy produces as its final result, cold; in the latter, heat produces as its final result, mechanical energy. In both cases, with a certain amount of useless effect or loss, inevitable to every machine in practice; and as in the latter case the power evolved must be *expended* somewhere; so in the former, the heat evolved, the equivalent of the mechanical power employed, must be *dissipated* somewhere, if the action in either case is to be continuous.

If Siebe's ice machine, in which the vaporizable liquid is sulphuric ether (or in any similarly acting machine with other volatile liquids), if its action were *theoretically perfect*, the mechanical energy (*i.e.*, the steam power) required to produce 1 pound avoirdupois of ice by its action is given by the formula,

$$E = 109{,}624 \times \frac{T_2 - T_1}{T_1 + 461{\cdot}2}$$

in which T_1 is the temperature at which the ether is vaporized.

T_2 that at which it is again liquefied (or as it is called in the steam engine condensed).

461·2°. The absolute zero—*i. e.* the theoretic temperature at which vaporous elasticity is = 0.—, and the co-efficient 109,624 = the mechanical equivalent of the latent heat of fusion of one pound of ice, in foot pounds—all these being taken on the Fahrenheit scale.

In a *theoretically perfect* machine, it is obvious that E, the mechanical energy required to make one pound of ice, will be much less than the actual power expended, but to what extent can only be experimentally determined.

As regards the ether machine of Mr. Siebe, we believe no data have been obtained of a strict character; we can *approximate* to the useful effect, however, from data with which we have been favored by that gentleman. An ice machine in their own possession, is driven by a high pressure engine, with 11 inch diameter cylinder, 3 feet stroke, running about 300 feet per minute, and working with 30 lbs. steam in boiler; this gives about 24 actual horse power. The engine, moreover, works certain shafting, &c., unessential to the ice machine, admitting of a slight deduction in actual power consumed, in the production of 5 tons of ice in 24 hours, or nearly 8 pounds of ice as the product of 798,000 foot pounds. This would seem to indicate that the loss of useful effect in the machine is small, although the actual power required is large, as it is evident it must be from the large amount of energy represented by only 1° of heat, viz: 779 foot pounds. The main losses of useful effect must exist, in the inevitable inefficiency of

the exhausting and condensing pump, in the agitation and lifting of the brine, and in the absorption of heat from the surrounding air, and its production by friction, &c., in the solids and liquids in motion in the machine. Measured in coal consumed, it gives about 6·5 lbs. of ice produced by 1 lb. of coal, assuming the engine not to burn more than 3 lbs. of coal per hour per H. P.

Mr. Siebe's machine, as shown in elevation, consists essentially of a double-acting air pump, driven by a band from the engine, and a connecting rod and crank from the fly-wheel shaft. This pump exhausts the vapor of ether from the liquid ether contained in a refrigerator, consisting of a large number of parallel copper tubes united at the ends, and provided with a glass gauge to show the quantity of liquid within. These tubes are wholly immersed in a saturated solution of common salt, or brine, which does not freeze under a cold of +4° Fahrenheit. The brine here refrigerated is the carrying agent by which the heat to be robbed from the pure water required to be made into ice, is taken from it, and transferred to the vaporizing of ether.

In a long wooden cistern, also filled with brine, they are placed transversely to its length, but not in immediate contact with each other, a considerable number of tinned copper rectangular troughs, each about eighteen inches long, as much deep, and about 2 inches wide. These are all immersed in the brine, and are filled with the water to be frozen; they are put in at one end, the lower one, and removed. when the ice is formed at the other. A constant circulation of the brine through the interspaces of the refrigerator, and those of the trough, is preserved by means of a small centrifugal pump, also worked by a strap, and the directors of the current of brine through the trough, is reversed to that in which the ice-moulds or troughs, march, so that the coldest brine first meets the water that has been already most cooled. The frame which holds all the ice moulds is provided with arrangements, by which the series is moved forward, or towards the upper end, when the water in any of the troughs is completely frozen. These troughs or moulds are lifted out, separately, and dipped nearly to the brim for a minute or so into warm water, by which the copper of the mould is a little expanded and a film of water formed on the exterior of the parallelopiped block of ice, by which means it is easily slipped out of the mould, which is then ready to be filled again with water, and being reintroduced to the freezing trough, proceeds on its way to solidification.

The vaporized ether from the vessel within which it is evaporated in this climate at about 20° Fah., and with a tension of about 26 ins. of mercury, is exhausted by the pump, through the tubes, and delivered at each change of stroke, into a large coil of copper tubes (forming, in fact, the *ether cooler*) contained in the large vessel of water passing through tubes, provided with stop valves in case of either vessel requiring opening, &c.

Round the coil in a vessel of water, common water of the ordinary temperature, about 53°, in this climate, circulates, and is kept renewed

either by the pump or by a constant flow from an elevated source. The ether is condensed into a liquid again in the cooler, at about + 80° Fah., and its tension is about + 7 inches of mercury, so that the total resistance to the pump, on the unit of piston surface, is about 33 inches of mercury, or rather more than 1 atmosphere.

There are manometer gauges on the tube, and on that leading to the large vessel of water, by which the tension at each side of the pump can be read off. The ether, after being liquefied and cooled down to something approaching the common temperature of well water in the large vessel, runs back to a self-acting valve, by which its delivery into the refrigerator again is regulated so as to accord with the abstraction from it by vaporization. A small pump is provided by which, in case of too much ether lodging in either the refrigerator or the vessel of water, the proper proportion can be restored by simple transfer from one to the other.

This is, in brief, the whole of the apparatus—as remarkable for its simplicity as for its singular effects.

The total quantity of ether employed in a machine of the size exhibited at the International Exhibition, making one ton of ice per day, is about 64 gallons imperial; and the loss, by leakage of the vapor, is stated by the makers not to exceed 1 lb. avoir. of ether, to the ton of ice made.

The largest machine Messrs. Siebe have designed, is arranged to make 10 tons of ice per day, and, as is obvious from what has been said upon the causes of loss and effect, the economy of working rapidly increases with the size of the apparatus. The cost of a machine fitted up at Geelong, in the colony of Victoria, to make 4 tons per day of 24 hours, exclusive of the 12 horse power engine (nominal power), was £1200, and several others have subsequently been erected in Australia, which we are informed, are prosperously at work, and have quite undersold there, the American imported ice. The slabs of ice produced are not as glassy and transparent as Norway or American ice, and this slight eye sore, of milkiness in appearance, is the only little defect in the entire machine. It is one that we ourselves, having at one time devoted some attention to the laws under which the crystals of ice form, in circumstances such as the present, are satisfied may be removed, and that ice as transparent as that of nature may be readily produced. Blocks of any magnitude, may be formed from the slabs taken from the mould; for when laid together like bricks, they rapidly solder themselves together into a single mass, by the effect of *Regelation*, the physical nature of which has been so beautifully deciphered by Faraday.

The original inventor of this form of ether ice machine was Mr. James Harrison a gentleman of Geelong, and a member of the Legislative Council of Victoria. After fruitless efforts in his own country to get his invention into practical form, owing to the want of any efficient mechanical assistance, he, with the strong faith of the true scientific inventor, who knows, that what is based on true science, cannot be abortive in practice, undertook a journey to England from

the Antipodes, for the special purpose of getting his ice machine constructed. In 1856 he patented his first machine (No. 747) in Great Britain, and in 1857 (No. 2362) he patented various structural improvements; finally, in March of last year, Mr. Siebe patented those improvements (1862, No. 782) which have brought the machine to what it was as exhibited, and here described. He has supplied machines of the largest size to the East India Government for making ice for the Indian military hospitals, has sent them, to both South and North America, and by their help it is, that the ice houses on board the Peninsular and Oriental Company's ships are now replenished in Egypt, and elsewhere further east.

The second ice making machine, that which was exhibited in the French department of the late Exhibition by M. Carré, depends upon principles fundamentally the same as those precedingly referred to. The fluid employed, however, is different, and the machine itself is constructed in two different forms; *en petite*, for domestic use, &c., in a way in which all motive machinery is avoided, and, *en grande*, for making ice by the ton; both forms were shown in action. The liquid employed in this case is fluid ammonia. Ammoniacal gas, existing, at ordinary temperatures and pressures, only as an elastic fluid, may, like the vapor of ether, be reduced to a liquid form, either by reduction of temperature, or increase of pressure. The liquid gas has a specific gravity of 0·73. The tension of its gas, at the freezing point of water, being=4·44 atmospheres, and at 65° Fah.,=7 atmospheres. The gas has an intense affinity for water, by which, at common temperatures, it is instantly absorbed with rise of temperature. One volume of water, at the freezing point, or close to it, absorbs no less than 1147 volumes of the gas, and at 60° Fah. still retains 783 volumes, at 212° Fah., the whole is expelled from the water.

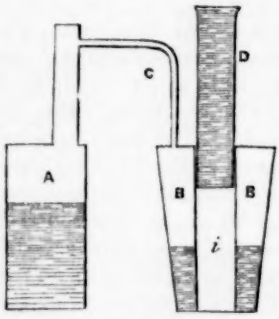
The liquified gas, first produced by Faraday many years ago, is seldom seen out of the laboratory; the watery solution, under the name of *Aqua Ammonia* of the Pharmaceutists, is well known; when saturated with the gas, it has a specific gravity of only 0·850, by which it will be remarked how largely the volume of the absorbent water is increased.

The principles of action then of M. Carré's ice machine rest upon the fact, that if we enclose in a strong vessel, say of wrought iron, such a saturated *solution* of ammonia, the vessel communicating with another closed vessel of about one-fourth the size, by an intervening tube, all being filled with ammoniacal gas; and if while the second or empty vessel is immersed in a large quantity of cold water at common temperatures, we gently heat the first vessel which contains the watery solution of ammonia, then ammoniacal gas will be driven off from the latter, the tension within both vessels will rapidly increase, and after a time, *liquefied* ammoniacal gas will condense (as if distilled over) in the colder vessel. If now we reverse the process, immersing the vessel containing the liquefied ammoniacal gas, in a relatively *small* quantity of water, which we desire to freeze, and keeping the other vessel, which contains the water, partly deprived of its evolved am-

monia, moderately cool, as by immersion in a *large* volume of common spring water; the highly volatile liquid gas will again become gaseous, and, as it does so, will be again absorbed by the now cold water, whence it came, and into which it will now return; but in this enormous expansion in volume of the liquid ammonia, sensible heat is robbed from the small quantity of water that surrounds the vessel, becoming latent in the gas evolved, and the water will be frozen. As soon as this has happened, and that all the liquefied gas had gone back and been again absorbed by the water, the whole process may be recommenced, and so on for ever. It is needless to point out that essentially the conditions are alike, with those of the ether machine.

The actual apparatus on the small scale, as exhibited by M. Carré, is shown in fig. 1. A, is a cylinderical retort or vessel, provided with a head or tube at top, and having also a valve capable of being closed absolutely tight, a thermometer attached, and communicating always by the tube C, with another vessel, B B, which is formed exteriorly as a frustrum of a cone, and has a hollow cylindrical space centrally within it, open at top and bottom. The enclosed space between these outside and inside surfaces, is that with which the vessel, A, is in communication by the tube C.

Fig. 1.



The larger of the vessels shown had a capacity of four gallons, or thereabouts, and both vessels are made of wrought iron tinned. Cylindrical copper vessels are prepared to fit with some exactness of contact, against the internal surface of the cylindrical space, *i*, of the vessel, B B, and into these the water to be frozen is put.

The vessel, A, is about half-filled with the watery solution of ammonia, above described, and hermetically closed.

Now to put the instrument in action, the vessel, B B, is wholly immersed in a large volume of common cold water, or in water cooled more or less by evaporation or by any other simple means, and the vessel, A, is at the same time gently warmed by hot air, or a gas flame, or small charcoal fire, &c., to 250° or 280° Fah. The ammoniacal gas is nearly all driven off, the tension rises, and gradually it condenses as liquefied ammoniacal gas in B B. The whole apparatus is now removed, and the application of cold water as before to B B, is now made to A, and at the same time a cylinder full of pure water, D, at the common temperature is inserted into the space, *i*, of the vessel, B B.

The relative warmth imparted by this, to the liquid gas within, B B, aided if need be, by the exposure exteriorly to a moderately warm atmosphere, causes the liquid within now to return to the gaseous state, and as it is evolved it is again absorbed by the water in A. The frozen cylinder of water is removed and another substituted, and when all

the liquid gas has gone back and been again absorbed by the water, the chain of operation is recommenced.

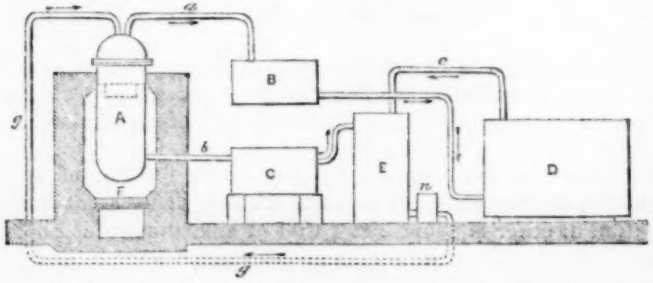
We have thus an extremely powerful freezing machine, devoid of any motive parts, requiring no fresh supply, except of the common cooling water, and presenting to the popular gaze, as near a likeness to a perpetual motion as can well be imagined. It produces, it is said, 11 or 12 pounds of ice for the pound of charcoal burnt, and a degree of cold reaching—40° Fah.

The greater machine which was also shown by M. Carré, and we believe also shown in action, is identical in principle, and only differs from the preceding in size, and in being provided with motive parts and power, so as to give continuous in place of intermittent action.

The diagram, fig. 2, will give a distinct idea of its arrangement. The pump, *n*, delivers the aqueous solution of ammonia through the tube, *g*, *g*, into the top of the boiler, A, which is strongly made of wrought iron, and is placed in a furnace capable of gently heating it. The solution is scattered by a rose and falls as a shower within it, and upon its warmed sides, evolving the ammoniacal gas, which passes off by the tube, *a*, while the warmed water passes out by the tube *b*. In both the vessels, B and C, are placed coils of tubes, like surface condensers, immersed in cold water. The gas becomes liquefied by the cooling in B, with the tension nearly due to the temperature, and the water that gave it up is cooled in C.

The liquid gas passes from B, on to the large vessel, D, which consists of cylindrical copper ice moulds, arranged like tubes of a locomotive boiler, for holding the water to be frozen, and with brine circulating between, as the carrying agent. Here, by the relative warmth that the water to be frozen imparts to the liquid, it again becomes

Fig. 2.



gaseous, robbing the water of heat, and carrying it off as its own latent heat of vaporization. The gas passes out of the refrigerating vessel, D, by the tube, *c*, and coming in contact with a shower of the cooled water pumped out of C, and delivered from a rose at the upper part of the vessel, E, is again absorbed by the water, and falls to the bottom as water of ammonia, ready to be again pumped into the boiler, as before, where it is again split up into gas, and warmed water.

Such is the whole arrangement, one almost as simple as that of the

ether machine, and possessing unquestionably a most energetic power of congelation, but having also the serious disadvantage, of visiting an extremely violent tension upon the apparatus; one, which in the case of the domestic instrument at least, might readily, owing to a little awkwardness in overheating, convert it into a veritable petard; and one, the explosion of which, evolving enormous volumes of alkaline gas, in an undiluted state wholly irrespirable, might be attended with very formidable results.

Professor Rankine, to whom also we are indebted for the theoretic formula of the ether machine already given, considers that were this apparatus *theoretically perfect*, the *expenditure of heat* to produce 1 lb. of ice should be as follows—

Let h = the latent heat of fusion of 1 lb. of ice.

a = the latent heat of gasification of 1 lb. of ammonia (pure).

b = the quantity of heat required to overcome the chemical attraction between 1 lb. of ammonia (pure), and the water in which it is absorbed.

Thus the total heat expended per pound of ice made is

$$\text{H} = h\frac{a \times b}{a} = 142 \times \frac{a \times b}{a}$$

as the specific heat of fluidity of water is about 142° Fahrenheit. This, however, is far from taking account of all the conditions of the question, some of which, as encountered in the practical working of these machines, are very complex. As the calorific power of 1 lb. of coal is about 100 h, if the machines were theoretically perfect, we ought to obtain, assuming $b=0$ which is possible, 100 lbs. of ice by the combustion of 1 lb. of coal. The result of actual practice, we have been informed on good authority, was the production of about 19 lbs. of ice, to the pound of coal, or its equivalent in other fuel, consumed in the large machine.

Assuming this, it is remarkable, that the duty from equal expenditures of fuel in the ether and ammonia machines, appears to be almost precisely proportionate to the latent heat of vaporization, of these respective bodies.

The ether machine appears to give about 6·5 lbs. of ice to the pound of coal; the ammonia machine 19 lbs. The latent heat of vaporization of ether is about 302°, that of ammonia about 838°, but

$$65 : 19 :: 302° : 883°.$$

The American ice machine has been patented in France, by two different parties, viz: by M. Carré, on the 24th August, 1859, and by MM. Tellier, Budin, and Hausmann, (*pere*), on the 25th July, 1860. It would appear therefore that abuses of French Patent Law are not unknown, more than they are with ourselves; for the second patentees themselves declare, that "their apparatus is exactly like that described by M. Carré."

The latter gentleman communicated a brief, but lucid account of his invention, to the Academy of Sciences of Paris, on the 17th Decem-

ber, 1860, which is published in the *Comptes Rendu* of that year, tome 52, p. 1023, and which led to a rather angry reclamation on the part of MM. Tellier, Budin, and Hausmann on the 28th January, 1861, (*Comptes Rendu*, tome 52, p. 143), to which M. Carré simply replies at the next sitting, 4th Feby., 1861, (same vol., p. 208), by quoting the dates of the respective patents.

M. Carré, in the communication above referred to, gives some interesting facts as to these curious machines. With his larger apparatus he has obtained a degree of cold—76° Fahrenheit, with the ammoniacal solution, containing only 20 per cent. by weight of the gas. The liquefaction of this ammoniacal gas, though not quite free from water, readily takes place at 45° Fahrenheit, at a pressure of 6 to 7 atmospheres. M. Tellier and the others, however, in their communication to the Academy, affirm that even at 37° Fahrenheit this varies from 4·4 to 8·5 atmospheres pressure, and that as the heat of the furnaces may be by mismanagement too great, and from other conditions, which they mention, the apparatus must be made strong enough to bear with safety 10 atmospheres. Its rupturing resistance must therefore be, with a reasonable margin of safety, equal to at least 30 atmospheres. This actually great, and liability to still greater pressure, and the probability that every metal (except perhaps the noble ones) will be more or less rapidly acted on by the ammonia and rendered brittle and unsafe, constitute the only objectionable points in the system of Carré.

Cast, or wrought iron, or steel, tin and lead for solder or other joints, are the only metals that can be employed. Brass, or any alloy of copper and zinc, are almost instantly rendered brittle, he admits. Our own experiments, as well as some, not published, which we are acquainted with, by others, cause us to believe that crystallization, and hence the becoming brittle of wrought iron under the action of gaseous ammonia may only be a question of time. In fact, ammonia seems to have an energetic power of forming azoturets or nitrides, with a large number of the metals. MM. Tellier, &c., accordingly state that for domestic use they prefer to employ liquid sulphurous acid, which, although not absorbable by water in nearly as large proportions as ammonia, becomes liquefied at about one-half the pressure, for equal temperatures.

M. Carré states that the ammonia, in being absorbed by water gives out heat equivalent to that absorbed in the refrigerator. If the weight of ammoniacal gas absorbed be 30 per cent. that of the water, and taking the heat evolved in absorption of 1 kilo. = 2·204 lbs. of ammonia, as equal to 514 *calories* = 2039·5 British units of heat, then 1 kilo. of water in becoming saturated to the above assigned amount, without change of temperature, will require the withdrawal of 154·2 *calories* = 611·86 British units of heat.

M. Carré concludes his communication by recapitulating a large number of important purposes, both purely scientific and industrial, to which this cold making machine, may be advantageously applied.

Amongst these, perhaps, none are so fraught with the probabilities

of great future results as is its employment, for separating the saline contents from sea water.

Already, he states, MM. H. Merle et Cie, the great salt makers of the department *Du midi*, have arranged to employ it on a very large scale. By slow congelation, the ice formed from sea water is absolutely pure and free from salt. The expenditure of heat units in producing salt (with theoretically perfect machines) by evaporation and by congelation, for equal weights, he shows to be in the ratio of 643·25 : 103·00; the latter will, therefore, be theoretically, by 6 to 1, the cheaper mode of procuring fresh water for supply of ships at sea, in place of by distillation. For the cooling of air, in tropical or other climates, M. Carré states his opinion, that it can be effected, by means of the ammonia ice machines, at a cost not exceeding double that, at which air can be warmed to an equal number of units, by means of the French *Calorifere*, *i.e.*, by several of the forms of heating apparatus.

MM. Tellier, &c., however, say that from any given zero, equal increments or decrements of heat ought to cost alike. We are by no means as yet, assured that either are, *practically* considered, even approximately right. As a result, however, of some rather careful consideration, we have come to this conclusion at least, that on board our ships of war, stationed on the African and West Indian Coasts, and still more on board the Peninsular and Oriental Company's Mail Steamers, there would be no practical difficulty whatever, nor any serious amount of cost, in continually ventilating the whole of the sleeping and dwelling parts of the ship by air continually renewed, and kept down, even in the Red Sea, to 60° Fahrenheit, by suitable adaptations of machines of this class.—Ed.

Results of an Experimental Inquiry into the Comparative Tensile Strength, &c., of various kinds of Wrought Iron and Steel. By David Kirkaldy. London: Hamilton, Adams & Co.; Simpkin, Marshall & Co., 1862.

From the London Civ. Eng. and Arch. Jour., April, 1863.

We return to the consideration of Mr. Kirkaldy's volume, the limits of a single notice not allowing the due mention of many of the important facts and data contained in its pages.

We have as yet adverted only to the experiments on rupture. These were accompanied with observations of the ultimate extension of each specimen, but as it appeared further to be very desirable to find the amount of strain required to produce a perceptible increase of length, and also to learn the rates of elongation as the strain was gradually increased from this point up to rupture, a set of experiments were conducted with great nicety for this special end, and the results are collected in a separate table. In another table a selection of these results is arranged in the order of the descriptions of metal tested, with the strains reduced to pounds per square inch, and the elongation to decimal parts of the original length. As very various qualities of iron and steel bars, iron and steel plates, and angle iron were operated on, a wide

diversity of rates of stretching was only to be expected, and it appears that—

"The rate as well as the ultimate elongation varies not only extrmely in different qualities, but also considerably in specimens of the same brand. The following examples show some of these variations:—

	No.									Ultimate strength.	Ultimate elongation
Swedish, R.F. .	534	30000	·0200	40000	·0708	50000	. .	60000	. .	49122	·2570
Swedish, X. .	533	"	·0280	"	·0540	"	·1670	"	. .	50202	·1858
Bradley, Hoop L.	527	"	·0036	"	·0350	"	·0998	"	. .	56004	·2400
Bradley, B. B. Scrap,	517	"	·0004	"	·0228	"	·0850	"	. .	58571	·2500
Low Moor, .	504	"	·0030	"	·0190	"	·0800	"	·1420	62835	·2583
Farnley, .	502	"	·0045	"	·0210	"	·0670	"	·1490	64133	·2647
Govan, Diamond,	511	"	·0017	"	·0160	"	·0630	"	. .	59726	·2717
Ulverston, .	518	"	·0028	"	·0170	"	·0630	"	. .	58000	·2060
Ulverston, .	535	"	·0132	"	·0604	"	. .	"	. .	48870	·2388
Bradley, Crown S.C.	505	"	·0040	"	·0200	"	·0690	"	·1720	62344	·2534
Govan, Star, .	508	"	. .	"	·0775	"	·0405	"	·1075	60722	·1130
Russian, C C NO,	525	"	·0044	"	·0150	"	·0373	"	. .	56477	·0650
Crank-shaft, .	536	"	·0170	"	·0820	"	. .	"	. .	44591	·1754
Crank-shaft, .	537	"	·0230	"	·1070	"	. .	"	. .	43420	·2461

Several of the bolts were marked so that it could be seen whether they stretched uniformly throughout their length. With few exceptions this was found to be the case until very near rupture, when they more or less suddenly drew out at one part, or in some cases at two or even three; and the lateral contraction at fracture was found not only to vary extremely in amount, but also to be more abrupt in some specimens and more gradual in others. A number of the plate specimens were polished on one side, and a series of circles drawn, which were transformed more or less into ovals when the strain was applied.

A series of curves of elongation are given among the plates at the end of the volume, showing at a glance the very varied character of the results obtained, and clearly illustrating the greater or less abruptness with which the rate of stretching increases just before rupture.

The number of specimens tested, and the discrimination with which the experiments were conducted and the results classified, gives much value to the information Mr. Kirkaldy has thus supplied as to rates of stretching under the higher strains. The pieces (ranging from 20 to 30 inches) were, as our author remarks, too short to observe the minute variations under strains less than from 26,000 to 30,000 lbs. per square inch. For these we must still depend upon the conclusions of previous investigators, which, however ably formed, are very deficient in the two respects in which the inquiry before us is strongest —namely, breadth of induction, and precision in distinguishing the peculiar qualities of the several specimens.

The greatest elongation (in parts of the original length) had been stated by a high authority to be greater in shorter than in longer bars. Our author points out the reason of this hitherto unexplained fact, which becomes readily understood on looking at his elongation curves. The ultimate elongation is made up partly of a pretty uniform stretching of the entire length of the bolt, and partly, as we have seen, of a sudden drawing out just before rupture, near the place

of fracture. The former would give the same rate of increase in a long bolt as in a short one; the latter, being of equal amount in the two cases, would make the total elongation of the shorter bolt greater in proportion to its length than that of the longer one; but this difference must vary with the quality, temper, and shape of the metal, and the sudden or gradual putting on of the breaking strain.

It was also found that with rolled iron bars of the same brand, the smaller the diameter the less was the ultimate elongation; and this, notwithstanding that the breaking strain per square inch for the smaller bars was decidedly greater than for the larger. The rates of elongation for equal rates of strain were reduced in a marked manner as the bars were rolled down from their original to smaller diameters.

In trying how various treatment affects the strength of steel, Mr. Kirkaldy brought out a very unexpected and striking result, namely, that the strength of steel is prodigiously increased by heating it, and then plunging it in oil.

"For the first trial, six pieces were taken from one bar of 'chisel cast steel,' and forged into shape. 1006, Table N, was heated and allowed to cool slowly; 1002, heated and plunged into cold water; 1003, same as the last, but tempered to yellow shade by slightly heating; 1005, same as before, but tempered to blue shade; 1004, also heated, cooled as before, and brought to 'spring temper' with tallow; 1001, heated and plunged into oil, instead of water. Now, observe the varied results:—1006, soft, bore 121,716 lbs. per square inch; 1002, cooled in water, extremely hard, only 90,049 lbs.; 1001, cooled in oil, and hard, actually bore 215,400 lbs., or 96½ tons per square inch, showing a gain in strength of 77 per cent.; whilst 1002 shows a loss of 26 per cent., 1001 being 2⅔ths stronger than 1002. The other bolts, 1003, 1004, 1005, also show a loss in strength, respectively, of 17·0, 13·8, and 8 per cent. This singular effect of hardening in oil was fully corroborated by subsequent tests, shown in the Table. Various qualities of steel were taken, and the degree to which they were heated before immersion was varied, to observe the difference. The following is the percentage of increase in strength, beginning with the hard steels highly heated, and ending with the soft steels slightly heated:—7·90, 77·6, 71·4, 70·9, 65·1, 64·1, 58·5, 57·0, 55·2, 53·2, 44·8, 40·7, 29·5, 24·2, 15·6, 11·8. In a few instances coal-tar was tried, and in some tallow; but the results, although good, were inferior to those with oil, which was of the coarsest and cheapest description. Rivet steel heated, and cooled in water, shows a loss in 1035 of 24·4, and in 1042 a loss of 18·5 per cent. confirming the accuracy of the former experiment. Of course the writer was fully aware that oil had previously been used for hardening sundry thin articles; it was not, however, to increase their strength, but because they were distorted by immersion in water."

Steel plates similarly treated also showed a great increase of strength; and trials by hammering under heavy strain, and by bending, showed

that the metal was not only hardened but toughened by being cooled in oil. Experiments on riveted steel plates established the further fact that the loss of strength caused by the rivet holes is more than counterbalanced by the increased strength of the hardened plate.

It is to be remarked that the tensile strength of steel established by Mr. Kirkaldy's investigation is very far below that obtained by Mr. W. H. Barlow from experiments conducted at the Royal Arsenal, Woolwich (of which a notice appeared in this *Journal*, vol. xxv. p. 39.) The reason of this is very satisfactorily traced to the different forms of the specimens tested in the two cases; Mr. Kirkaldy's being in the ordinary shape of bolts, while Mr. Barlow's were short thick blocks gradually tapered off towards the middle to a minimum section. The strength deduced from the Woolwich experiments is between 30 and 40 per cent. more than that given by the experiments now before us; and from his own trial of the effects of merely altering the shape without altering the minimum sectional area, our author shows that this difference is anything but surprising. The Woolwich test having thus been exceptionally favorable in its conditions, Mr. Kirkaldy's results must be taken as the real indication of the tensile strength of the metal under ordinary circumstances.

Experiments on the strength of welded joints, different sizes and qualities of iron being employed, all concurred to show the extreme uncertainty of such work, even in the most practised hands.

"The pieces were cut through the middle, and then scarfed and welded in the ordinary manner by the same smith who prepared the bolts for the other experiments, and a few by a chain-maker, for comparison. The result varied greatly,—fourteen, as operated on by the smith, show a loss, compared with the original whole bar, from 4·1 to 43·8 per cent., the mean loss being 20·8 per cent.; four by the chain-maker, from 2·6 to 37·4; mean, 15·1 per cent. Of the former, four broke solid, away from the weld; eight, partly through solid portion and partly at the weld; two separated at the weld. Of the latter, two broke solid, one broke partly solid and partly at the weld, and one gave way at the weld."

The following experiments on the effects of frost upon wrought iron, while they do not go as far as could have been wished, are not without interest. They would seem to show that in iron of good quality the loss of strength from this cause is less than might be thought.

"Frost being considered to act injuriously on the strength of iron, some experiments were made during the severe weather in Dec. 1860, to ascertain is effects. A bar of Glasgow B Best, ¾-inch diameter, was converted into ten bolts in the ordinary way. Six were exposed all night to intense frost, and tested in the morning with the thermometer at 23° Fahr. The other four were kept in a warm place, and carefully protected during testing. Three were tested with gradual, and seven with sudden strains. When the strain was gradually applied there was very little difference between the specimen tested in the ordinary condition and the two that were frozen; the former bore

55,717, the later 54,385; difference, 1332 lbs., or 2·3 per cent. less. The difference under sudden strains is somewhat greater, viz: 3·6 per cent. less when frozen. The load just sufficient to cause rupture was in the one case somewhere between 50,835 and 49,948; in the other, between 49,060 and 48,109; the mean in the one instance being 50,391, in the other, 48,584; difference, 1807 lbs., or 3·6 per cent. The writer regrets that other duties prevented him carrying out his intention of repeating these experiments with bars of various qualities. It will be noticed that the bar tested happened to be of superior quality; had it been of a coarser description, the difference when frozen might have been much greater. The frozen bolts were coated with a thin layer of ice, for the purpose of better observing the effects produced. In one specimen with strain slowly applied, the ice gradually became opaque and white, and just before breaking it resembled hoar frost. In another, under sudden strain, the ice remained transparent, and the instantaneous stretching of the specimen was most beautifully exhibited by the ice cracking and forming a series of complete rings. In another specimen the strain was greater than in the last, and caused the rupture of the specimen; the heat thereby generated was apparent by the ice melting, and in the formation of vapor."

The specific gravities of upwards of 160 specimens of iron and steel are given in a table, arranged according to the brands. The means range from 7·7677 for steel bars rolled, to 7·4276 for puddled iron rolled, the specific gravity generally indicating pretty correctly the quality. One result is remarkable as contrary to the common idea that the density of iron is increased by cold-rolling. Mr. Kirkaldy finds that the reverse is actually the case.

"The specific gravity of a bar in the ordinary condition was 7·6360; the mean specific gravity of four pieces cold-rolled was 7·5824; that of two pieces of boiler plate in the ordinary condition was 7·5664; and that of two other cold-rolled pieces was 7·5392. Instead of an increase we have a decrease in the specific gravity of 0·70 per cent. in the bar specimens, and 0·36 per cent. in the plate specimens, produced by the process of cold-rolling. The writer will now give proof of this fact in another form, by comparing the cubic contents of a bar previous to and after undergoing the process, thus:—

	Diameter.	Area.	Length.	Cubic Contents.
Ordinary state,	·825	·5310	35·06	18·6168
Cold-rolled,	·764	·4584	40·94	18·7669

We have here an increase in the bulk of this specimen of 0·1501 cubic inches, or 0·86 per cent."

Although these data show that it is not, as usually supposed, the case that the metal is consolidated by cold-rolling, there is no question as to its being greatly hardened and made capable of standing higher strains than in its ordinary state.

"'Blochairn Best' boiler plate; lengthways, 'cold-rolled' contracted 2·5 per cent. with 88,993 lbs. breaking strain; cold-rolled and afterwards annealed, 13·6 with 50,960; in the ordinary condition, 14·3

with 45,812; crossways, in the same order, 0·0 with 80,643, 7·2 with 48,674, and 7·7 with 43,020. These 'cold-rolled' pieces were extremely hard, as shown by the above figures, and by the strips splitting when being cut off at the shearing-machine, also by the broken pieces punched out for rivet holes.

"'Blochairn Best' bar; 7 pieces 'cold-rolled' varied from 26·8 with 78·466 to 39·3 with 68·718, mean 36·3 with 74,948; 2 pieces cold-rolled and then annealed, 45·2 with 62,285, and 47·6 with 56,477; 1 piece in usual state, 43·1 with 60,637.

"It will be noticed that the greatly increased strain borne by the pieces after being cold-rolled by Mr. Lauth's patent process, was consequent on the iron becoming very much hardened by the treatment."*

*For further remarks on this subject, See Journ. Frank. Inst., pp. 310 and 397 of Vol. xlv.

W. Clissold's Driving Belt.

From the London Mechanics' Magazine, March, 1863.

We last week alluded at some length to the interesting subject of machinery belts, and we also gave a short account of the belt patented by Mr. W. Clissold, of Dudbridge, Gloucester. The following is a description of this novel mode of constructing that class of driving belts which bind by lateral pressure on their pulleys, and thereby take so firm a hold as to remove the liability to slip, which is a disadvantage common to ordinary driving belts. This improved class of belts (which already forms the subject of letters patent granted to Mr. Clissold, and bearing date May 22d, 1860, No. 1266), may be described as an endless band beveled at its edges to fit into V-grooves formed in the periphery of the driving pulleys, such band being composed of layers of leather or other material connected together by pins, or otherwise. In practice it has been found that the beneficial thickness of which these belts may be made is limited, by reason of the unequal strain upon the outer and inner layers, or parts of the material composing the belt, and, consequently, that the strength of such belts cannot with advantage be indefinitely increased. From this cause it was deemed necessary to limit the application of belts constructed of a wedge or taper form in cross section to uses where no great strain was likely to be experienced.

The object of the present invention is to increase the strength of belts of this class, so as to render them equal to the heaviest work to which it has hitherto been or may hereafter be found desirable to apply driving belts or bands. To this end, instead of making beveled-edged belts as heretofore, with one continuous length of beveled edge, they are formed of links, which, while presenting good contact surfaces to the V-grooves of the pulleys (against which they will press laterally without touching the bottom of the grooves), will so divide the unequal strain upon the inner and outer surfaces of the belt hitherto found so destructive to the wedge form of belt as to render the strain nugatory. The friction or wedge-shaped links may be made of strips of leather or other flexible material coiled up to the ordinary

figure of a link, or they may be made of moulded rubber, or other suitable plastic material. These links are connected together by link plates carrying a stud at either end, which studs will enter the space in two adjacent flexible links and hold them together, forming in fact fulcrum pins for these links to turn on as they pass around the driving pulleys.

FIG 1

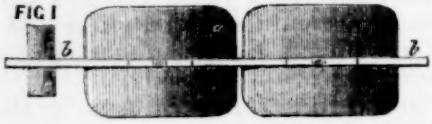
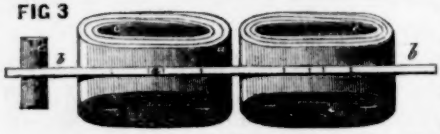


FIG 2

FIG 3



The accompanying engravings show the improved construction of link driving belts in several views, the friction links being in this example composed of coils of leather. Fig. 1 represents the outer face, and fig. 2 a side elevation, of a portion of the belt drawn to full size; fig. 3 is a view of the inner face of the belt, and fig. 4 is a cross section showing the application of the belt to a V-grooved pulley.

FIG 4.

The wedge-shaped links *a*, *a*, fit into the groove of the pulley, but not so as to bed therein, the object being to allow of the belt tightening on the pulley by sinking deeper into the groove as the breadth of the links decreases by wear. These links *a* are each made by preference of two parts to facilitate the forming of sockets for the reception of the link plates *b*, *b*, and the parts *a*, *a*, are coupled together in the middle by filling pieces *a** cemented thereto, or otherwise attached to the parts *a*.

From the above explanation it will be understood that this mode of making driving belts permits of any strength of link being used according to the work to which the belt is to be applied. The patentee also remarks that belts constructed on this principle may be made wholly of metal, in which case he prefers to line the V-grooves of the pulleys with wood, to prevent the grinding of metal against metal.

Institution of Naval Architects.

From the Lond. Mechanics' Magazine, April, 1863.

The ordinary meetings of this institution took place last week in the large hall of the Society of Arts. A large number of members, associates, and friends were present. The Right Hon. Sir J. Pakington, occupied the chair.

The following is merely an abstract of some of the principal Papers read and discussed. On Thursday morning four Papers were read in succession upon the great subject of iron-clad ships—by Mr. W. Fairbairn, "On the Construction of Iron-plated Ships;" by Mr. Samuda, "On Iron-plated Ships;" by Mr. Scott Russell, "On the Present State of the Question at issue between Modern Guns and Iron-coated Ships;"

and by Mr. E. J. Reed, of the Admiralty, "On Iron-cased Ships."

Mr. Fairbairn's Paper had reference chiefly to the importance of the working of the iron, and the methods of obtaining the greatest mechanical strength. As a rough statement it might be said that thickness of plate would represent strength, but much depended upon the processes of hammering and rolling, by which the fibre and texture of the metal were improved. He recurred to the views he had expressed in former Papers, which were founded upon many experiments, and said that the cellular structure employed in tubular bridges and girders was the best form for obtaining greatest strength. He advocated the use of this principle in the construction of iron ships, and would have the cellular compartments run the whole length of the bottom and sides of a ship, her armor plates to come above this, and the decks to be made very strong means of support by making the beams of iron. A ship ought to be so stiff that she would bear suspending on two points, one at each end, or even upon one amidships. As to steel, it was difficult to say what might not be done with it, as its strength was much greater than that of iron; still, as yet it had not been sufficiently tested. He was not inclined to building very large ships. He showed a diagram of a vessel in which he would arrange the heavier burden of engines and guns in the middle, and these to be protected with more extensive armor plates, while a belt might be carried round the ship at the water-line, covering the steering apparatus and screw, but leaving parts unprotected. As to large guns, he was much of opinion that the limit of their strength had been attained in the 300-pounder.

Mr. Samuda's Paper commenced by stating that an efficient navy was and must always be of the first importance to this country, and that no navy could be efficient except it be armor cased, in order to meet all artillery that might be brought against it. Partial protection was no longer upheld as a necessity, and entire protection, in deference to a strongly-expressed opinion of its necessity, had been substituted in all the vessels that had since been commenced. Entire protection, the greatest speed obtainable, armor which admitted of the easiest replacement, and, lastly, which added strength to the vessel by being incorporated into its structure. Those four points could not be too frequently urged as indispensable to an efficient iron-clad navy. Although he held that plating wooden ships in armor was but a make-shift, and that real service and bad weather would lay bare the fallacy of expecting it to be any thing but a temporary job, yet he felt it was satisfactory to know that some proper amount of protection was about to be given to the country, even though it should be limited to the Government dock-yards. He could not help expressing the surprise and indignation he felt, in common with other leading shipbuilders, who had all contributed most loyally to advance the success and welfare of the navy, and who had not hesitated to place themselves and their establishments at the disposal of the Government without any adequate profit, when the construction of the iron navy was of imminent importance, to find themselves referred to by the

Controller of the Navy and the Admiralty in terms of censure and reproach, as a reason for the asking Parliament to give back to them the privilege and patronage of again building in their dock-yards vessels which had far better have been built of iron than of wood, and in private instead of in public dock-yards. The period had arrived when they must consider whether any and what general improvement in the character of those which would have to follow should be adopted, and a consideration of the relative advantages of portholes and cupola ships would lead to the solution of that important question. The cupola reduced materially the weight of armor required to be carried on the top sides of the vessel. If 4 feet be fixed in both cases as the extent of under-water protection, the cupola vessel only required a total depth of armor of 11 feet against 20 feet for the porthole. The 11 feet gave perfect protection to the cupola vessel, while the 20 feet only yielded partial protection to the other, every porthole being assailable by shot and shell. The next advantage was the facility of working much heavier guns, the advantage of moving them mechanically, and the very much greater range obtainable rendered every gun in a cupola ship at least equal to two worked in a porthole ship, and in many instances to much more. Another advantage was the concentration of the crew, and their extra protection in all circumstances. Also the rolling of the vessel would interfere with the working of the guns, where they had to be fired from ports, long before it would have reached a pitch to prevent working them in cupolas, and where they were fixed from over decks; and, lastly, the power which that mode of keeping down the tonnage of the vessel, and at the same time obtaining a high velocity, was of the greatest importance. The importance of obtaining that result at an early period was what he desired; and if he could sufficiently engage attention to the importance of that conclusion, he should have obtained the object he had in view in writing that Paper. The *Prince Albert* was an excellent beginning, having many advantages, but it should have 800-horse power instead of 500, and that change would make it a 13-knot ship, and much improve the character of the craft. He suggested that the Admiralty should build five additional *Prince Alberts* in private yards at the same time they were proceeding with the five porthole frigates in the dock-yards. The cost of the whole of those vessels would be only £1,000,000, and he was sure the House of Commons would vote it for such an important object. The result, he believed, would be that the cupola ships, far from being useful only for coast defence, would be found serviceable all over the world.

Mr. Scott Russell reminded the society that they were considered heretics two years ago for advocating iron ships. The question had progressed since then, and now the demand for the new navy was for ships with great speed and immense strength. They must be 14-knot ships; they must be long to have speed, and broad to have stability, and keep their ports 9 feet out of water. He put the case of there being an *Alabama* upon the track of our China and Australia trade; he would not call her a pirate, but supposing such a ship in time of

war, we had only two ships that could chase her—the *Defence* and the *Resistance* would only follow in her wake. We saw the whole available American navy engaged in trying to catch this *Alabama*. Mr. Russell would do away with the timber-backing of the *Warrior*, and substitute iron plates. It did no good; it only caused buckling of the plates, tending to draw out the bolts, and took fire with shell, as we saw at Shoeburyness. The weight of this wood would be better exchanged for iron plating. Mr. Russell gave Mr. Pole's formula for the relative strength required for plates *versus* guns. For—

68-pounder,	. . . .	4½ inches.
130	"	6½ "
200	"	7½ "
290	"	8½ "
400	"	10½ "
500	"	11½ "
600	"	12½ "

We have now to provide against a 300-pounder sending shot with a velocity of 1500 feet per second, and we have to mount and fire this gun rapidly and easily to the ship ourselves. He could not but think that this would be done with all the able mechanics and engineers the country possesses. Captain Coles's cupola he had made himself, and this one had been tried successfully. The turntable was the only mode he knew of which enabled such heavy guns to be moved with so much ease; and by this means, too, the weight was kept in the central line of the ship. The *Prince Albert* he could not think a judicious application of the principle, and the *Royal Sovereign* was much worse. But give any one of our gallant naval officers a 15-knot ship, with a cupola forward and one aft, and the engines and rudder shot-proof, and he would be bound they would give a good account of any *Alabama* in the world. But if it was required to work guns even on the broadside by machinery, it was only to say so, and there were plenty of mechanics who could do this. Mr. Russell intimated that he knew how to make a larger number of guns available than in a cupola. He could see how the 300-pounder broadside gun could be put on a par with the turntable 300-pounders. The portholes in the cupola have the great advantage of being small, but it would be quite practicable to work a 300-pounder at any elevation in an opening which shall not be larger than the muzzle, only sufficient to allow of aiming. As to weights of armor, he would expect to see used 7½-inch plates, with 3½-inch iron backing, in vessels 500 ft. long and 70 broad, of 12,000 or even of 22,500 tons—*Great Easterns*, in fact, 700 ft. long and 83 broad. Mr. Russell pointed out that the *Hector* and *Valiant* are not proof against shell at unarmored parts; they would be blown up by shell entering here. But we must adopt expedients of partial protection and partial battery. The *Warrior* has more iron in her than the *Great Eastern*, in consequence of its not being used with economy. Protection to the water-line he did not much care about, as the water-tight compartments serve the purpose of protection. He attributed

much to the labors of the Iron-plate Committee, and looked to next year to show us how much progress had been made in scientific knowledge and professional acquirement, and ended by saying that engineers and naval architects were ready to serve the Government, and to put up with loss rather than the service of the country should suffer.

Mr. Reed then followed with his Paper, which, after a few observations alluding to his having resigned his office of Secretary to the Society so as to avoid embarrassing them, referred chiefly to a defence of his plan of construction adopted in the *Enterprise* sloop of 950 tons, and an attack upon Captain Coles's cupola plan. His iron-cased ship was as unlike the *Monitor* as possible; it was well out of the water, well supported at every part, the armament in the centre, of few guns of long range, with the steering apparatus and engines protected by proof armor. He would armor-plate every ship of every size to a certain degree, giving them large guns with long range, and high speed. Anything like the *Monitor* would be a decadence, a disgrace to our pride and to the "flag that has braved the battle and the breeze." The form of our ships should never be compromised as it is in the cupola plan. They must have good handsome masts and rigging. He advocated wooden ships, and especially wooden bottoms in small ships particularly. But if 14-knot ships must be had, then iron is the only material to make them of; and this was according to the first design he had the honor of submitting to the Admiralty. He stated the evidence of the Surveyor of Lloyd's, that in some iron ships not 5 years old 1000 rivets had disappeared from the bottoms. And in private yards he knew of the plates being joined so badly as to require caulking, as the records of the society, he believed, would show. Still he would not deny that now no labor or capital is spared in private yards, and a high degree of excellence is attained. Mr. Reed described the *Enterprise*, and said the frame of this ship was of timber converted. She had her battery in the centre, in a water-tight compartment, with means for fore and aft firing of the guns. In the *Renard* and *Favorite* the iron upper work was avoided, and they were completely plated. He alluded to the severe criticisms his plan had met with from the press, and especially from Admiral Halsted, defending the *Enterprise* from the charges brought against her in that gallant officer's pamphlet. As to the cupolas, or turrets rather, of Captain Coles, they were exposed on at least 10 feet square on all points. The trials with the *Trusty* in 1861 he thought not conclusive, as breech-loaders were used. Then these cupolas could be easily wedged by boarders. He could see no prospect of such vessels being made sea-going, and in action, as the bulwarks are permanent, the guns could not be fired fore and aft. By an array of figures on the black board, Mr. Reed showed that the statement in the *Mechanics' Magazine*, 27th February, as to the weight of broadside being in favor of the cupola, was not only erroneous, but that the advantage was largely in favor of the *Favorite*. Guns of 20 tons he expected to see worked by machinery, and if we dispensed with these 120-ton turrets we could afford to use machinery. Small shield ships could not be constructed; and as to the ships now pro-

posed by Captain Coles, it was impossible to construct them as designed. Rapid turning of a ship with broadside ports like the *Favorite* would be gained by using the double-screw system and high speed; experiments upon which had recently been successfully made by Captain Astley Cooper Key. He did not regard the *Enterprise*, *Resolute*, and *Favorite* as specimens of the class of ships he conceived would become the future style of naval architecture.

Mr. Fairbairn stated that he had proposed in 1855 to the Admiralty to investigate the subject of iron plates for ships, but was not encouraged to proceed.

Admiral Halsted, in reply, admitted that he was mistaken as to the statements in his pamphlet about the *Research* having the iron box, as he called it, or rectangular cupola. He protested, however, against being provided with these ships-of-war, one-third of whose guns were useless, and maintained that no trials had ever been made of targets representing ships' sides until the ships were in progress of construction. The Whitworth shell, fired upon a target stronger than the *Minotaur*, in November last, had initiated a revolution in naval gunnery and shipbuilding, and henceforth it was shell that was more difficult to keep out than shot, for it penetrated with more facility than solid shot.

After the discussion, Mr. Lancaster, the well-known artillerist, stated, in reference to the future use of very large ordnance with shell, that he had seen in America lately, 400-pounder shells, of cylindrical form and hollow-headed, fired from an 18-ton gun, which pierced plates of 9 inches thick at long ranges. These guns were used in turrets, to which was attached a lower and smaller turret, in which the loading of the gun was managed by the crew of the gun; and this was much facilitated by using a small tramway, on which the gun worked.

At the meeting of the Institute on Friday, Sir J. Pakington in the chair,

Captain Cowper P. Coles described his plan of turret ships, especially comparing with the *Favorite* (a vessel on the plan of Mr. Reed), his own design, called the *Naughty Child*, being a ship of the same length, beam, and tonnage, and of equal power, speed, and draft of water. In the *Favorite*, the guns are at the two sides of the vessel, and are placed in a protected battery amidships, having a very limited range, and being in danger of dipping into the sea on the roll of the ship. In the *Naughty Child* he proposed to place a smaller number of guns—say three in two cupolas—which guns, from the facility of turning round the turret, would be as effective as a broadside twice the number. In the cupola, also, he had the advantage of keeping the gun pointed in the right direction, so that no time was lost after loading, but fire might be delivered at once. The same facility existed for keeping the guns pointed at an enemy while manœuvring the ship; while, in case of boarders, he could fill the spaces between the masts and stays with riflemen, as well as the tops of the turrets. The danger of the turrets being damaged by shot was not great. Sixty-nine shots were fired at the *Trusty*, by the best gunners in the navy, and only

forty-four hit the cupola. It was a great advantage of this plan, that by it guns could be trained and loaded at the same time. He read an extract from an account of a recent fight in America, showing that no injury had been sustained by the turret ships, although in one case the turret had been hit sixteen times, and that the guns were perfectly manageable. He said that the danger of wedging the cupola was small, and he thought little difficulty would be found in knocking out the wedges if the enemy succeeded in driving them in. He contended that the proper vessels for us would be shield ships, with a belt of armor reaching five feet above and below the water line, armed with a small number of heavy guns in cupolas.

Mr. Reed objected to estimating the force of a ship by the weight of its broadside. Round shot should not be compared with elongated projectiles. At Shoeburyness the 150-lb. round shot produced nearly the same effect as the 300-lb. elongated. It was not fair to deceive the public by such comparisons. He hoped that this discussion would have the effect of making gentlemen careful that their facts should be unimpeachable.

Admiral Halsted asked how a broadside ship such as the *Favorite* could be defended as well as a cupola ship like the *Naughty Child*, without using double the number of guns to produce the same effect.

Admiral Sir E. Belcher said that in the *Naughty Child* the guns were not in the centre of the turntable, and when the guns were on the lee side they must tend to prevent the ship from righting herself, while the guns on the two sides balanced each other. He had proposed a plan of three guns on one turntable, each placed at right angles to the radius, so that the recoil of one gun would bring the other into position.

Mr. Prideaux sketched on the board the outline of a plan he had submitted to the Admiralty, of a ship which appeared something like the cigar-shaped vessel they were building in Liverpool some years since.

Captain D'Orsay said draft of water was an element of little importance in the inquiry. We should build the best ships, no matter how deep they were. The effect of weight depended on its distance from the centre of gravity. Now the guns in the turret were nearer that centre than those on the broadside. Another great advantage was that they could be fought at longer angles, having a range all round the ship. In rigging, it was well known that the more rigid and unyielding it could be made the better, and he thought the tripod masts a great improvement.

Captain Scott said that a cupola ship must be unequally trimmed if she wants to give full effect to her broadside. The loss of a few plates of armor would throw the vessel up on the side next the enemy, and elevate the guns out of range. He did not think that the turrets allowed room to work the guns, and on the whole considered the plan of the midship battery the best.

Mr. Scott Russell said we should not pit the vessels against each other, but build both, and put them each to its right purpose. There

was not really much difference between the two ships; both could carry armor on the water-line and for five feet above it. Captain Coles placed the remaining spare weight in his ship in the form of cupolas, &c., and Mr. Reed placed it in that of a battery amidships. Were the cupola and guns heavier than the battery and guns? He thought they were at least as heavy. The heights out of water must be equal. The form most favorable for Coles' plan was a vessel with only two cupolas, which was as to these conditions on a par with Reed's ship. Then the differences were, that the latter could fight both sides at once, while the cupola ship should turn round her guns. To balance this disadvantage, Captain Coles could train his guns while loading, and could keep them on an enemy while moving. This was a great advantage. When he came to consider a vessel with a greater number of turrets than two, he thought the broadside ship had the advantage, but he said we ought to build both kinds, and do our best.

The Chairman said he must congratulate the Society on their having held a very interesting and instructive discussion, which had been conducted with great good humor. He would not presume to express an opinion; but he thought the case was like what happens in many families, where the favorite is apt to be a naughty child. He called attention again to the tripod masts, which he considered a great improvement, as with rope rigging it was only at the weather side that it acts, while on this plan the one side was a stay, and the other a prop.

This closed the discussion on the shield-ships.

The concluding meeting of the members of the Institute was held on Saturday, the President, the Right Hon. Sir J. Pakington, Bart., M. P., in the chair.

Mr. Scott Russell read a Paper on the "Education of Naval Architects in England and France." He commenced by comparing the state of naval architecture in England and France, and the means taken by the Government of the latter country to found, foster, and encourage a naval school of architecture, which had been found to work with the most admirable results. Little had, he said, been done in England to take the best means of educating men for that science; and it was only after considerable outward pressure some years back, that the Government had decided in founding a Naval School of Architecture. This was done, and a few students admitted; but in 1853 it was abolished by Sir James Graham, who was at that time First Lord of the Admiralty. It might naturally be asked how this had occurred, which could very easily be answered, as it was found that the Government had broken faith with the students of the school in every particular; and they discovered, after having made a sacrifice of some years of study, and made themselves efficient naval architects, that the Government declined to employ them, and there was only one instance in which the Government had given proper employment to one of the pupils, while all the rest who were competent naval architects were sent to the different dock-yards as supernumerary draughtsmen. This was not in consequence of a want of scientific knowledge on the

part of those gentlemen, as they all bore certificates of competency; in fact, the pupils of the School of Naval Architecture, although their talents had been to a great extent ignored by the Board of Admiralty, had since, by their own exertions and scientific knowledge, all obtained high positions as naval architects of the first class, and to them was due the credit of altering the sailing fleet into a steam one in a short space of time in a pressing emergency, by that fully repaying the cost of their education. In the case of those pupils of the school, Messrs. Chatfield, Crease, and Reed had written a report which he considered as a model of systematic naval architecture at that date. Those gentlemen had been given a chance to show what they could do; and the vessel they built, although their first, had every quality for which it had been designed. He then gave an account of the great progress France had made during the last ten years, both in the science of shipbuilding and manufactures, in which up to the present time we thought we were supreme, and instanced the way in which a great French Steam Navigation Company had driven the Peninsular and Oriental Company out of the Mediterranean trade, and had in addition commenced an opposition by running magnificent vessels to China. He also mentioned as a fact, that the Belgian locomotives had not only shut out the English ones from the continental markets, but that they were now brought over to England and undersold the English manufacturers. He concluded by regretting that at the present time the English were obliged to go to France to receive what he considered the requisite education on naval architecture, and strongly advocated the formation of a school or college of the kind, assisted by the Government, and explained the way in which it could be carried out.

Mr. Chatfield spoke, as one of the pupils of the School of Naval Architecture, of the efforts which had been made to put the school in the position it should occupy in this country, which were foiled and annihilated by Sir James Graham, who put them all aside for the purpose of introducing Sir William Symonds as Surveyor of the Navy. He was, however, succeeded by Sir Baldwin Walker, who frankly admitted that he was not a shipbuilder, and his doing so was the means of placing the most competent naval architects of the abolished school at his elbow—men who thoroughly understood the subject, and whose designs were carried out, although they did not get the credit for them. He approved of Mr. Russell's plan for founding a school of instruction on the subject, and agreed with him as to the necessity for it. He at the same time denied that any very great credit was due to the French for any designs sent to this country, as they had not been adopted. In fact, their pupils were in the habit of coming to the English dock-yards for instruction in their profession, and often went back as competent architects, having carried with them the ideas of the practical men of our own dock-yards, and taking credit for the designs they had seen here as their own.

Mr. Samuda disagreed with Mr. Russell as to the desirability of establishing a college for the sole purpose of instruction in naval ar-

chitecture, as he thought that the education received at an English college was sufficient until they came into a practical shipbuilder's yard.

Rear Admiral Sir Edward Belcher said he would have hesitated to occupy the time of the meeting had he not received some information on the subject during his business connexion with Sir R. Seppings, Sir Wm. Symonds, and Admiral Hay, from all of whom he had acquired some valuable information, in addition to some sound practice which he had himself acquired during his professional career. He then went into the question of speed, and compared some of the old line-of-battle ships with those of the present day, and claimed a rate of speed for the *Winchester* while under sail which had never been equaled by a man-of-war steamer—namely, seventeen knots. He also mentioned she *Southampton*, *Warsprite*, and *President*, the latter having been rebuilt after capture from the Americans, as ships of unequaled speed, which had beaten the best French vessels in all points.

After the meeting had been addressed by Dr. Woolley, Mr. Grantham, Mr. Reed, and others,

The Chairman said he was disposed to believe that Mr. Russell was right, that England was not in the position that it ought to be in a scientific point of view. All countries had, he considered, gone greatly ahead, in some cases eclipsing the English, and he advised them all to follow and consider Mr. Scott Russell's proposal, and strike out and adopt, after careful consideration, some plan of the kind which would give practical effect to the views so ably laid before them, in which he would co-operate in every way in his power.

Mr. Ditchburn, M.I.N.A., then proceeded to read a paper "On the Origin and Construction of Her Majesty's yacht *Fairy*," but after having read a portion, he, at the suggestion of the Chairman, withdrew the paper, as it contained some strictures on the professional knowledge of a chief constructor of the Royal navy who is now living.

Mr. Gladstone, C. E., read a paper "On an Instrument for measuring the Strain on Ships Cables;" after which Mr. W. Froude, A.I.N.A., read a paper "On a curious form of differential Wave in a stratified Fluid," with an experimental illustration.

An expression of thanks having been given to the Chairman before retiring, and also to the Secretary, who found that certain duties he had undertaken had rendered it necessary for him to resign, the meeting adjourned till the next session. Proc. Inst. Naval Architects.

On Sections of least Resistance for Ships of Limited Breadth and Limited Draft of Water.

[Read before the Glasgow Philosophical Society, by James Robert Napier.]
From the Lond. Mechanics' Magazine, April, 1863.

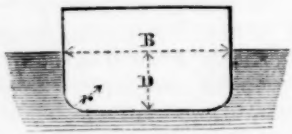
As the friction of water along the submerged surface of ships forms an important part of the resistance to be overcome, it is desirable that this surface be the smallest possible consistent with other conditions.

The common problem of passing a curve of a given length through

two points so as to enclose the greatest area between the curve and the straight line joining the points, may be applied to the construction of all vessels whose breadth and draft of water are not limited.

But there are many cases where both the breadth and draft of water are limited, it may be by the width of dock entrances and the depth of rivers. Then the problem becomes, to enclose within a rectangle of a given breadth and depth the greatest area with the least wetted boundary, that the enclosed area, divided by the wetted boundary, may be a maximum; for then, whatever form it may be considered necessary to give to the water lines, the vessel of this breadth and draft of water, with this midship section, these water lines, and with the narrow sections constructed on the same system, will have the greatest displacement or volume below water with the least surface for friction, and therefore the least resistance. In this sense I have called them sections of least resistance.

To construct these sections, the problem reduces itself to finding the radius of bilge, which, with the given breadth and draft of water, shall complete the section, whose area, divided by the wetted boundary, shall be a maximum.



Let B be the breadth of the vessel.
D the draft of water.
r the radius of bilge.

$$\frac{\text{Area of section}}{\text{Wetted boundary,}} = \frac{BD - 0{\cdot}429\,r^2}{B + 2D - 0{\cdot}858\,r} \text{ is to be a maximum.}$$

Therefore,

$$\frac{0{\cdot}858\,r\,dr \times \text{denominator} - 0{\cdot}858\,dr \times \text{numerator}}{(\text{Denominator})^2} = 0.$$

$$\therefore \quad r \times \text{denominator} = \text{numerator}.$$

$$(B+2D)r - 0{\cdot}858r^2 = BD - 0{\cdot}429r^2$$

$$0{\cdot}429r^2 - (B+2D)r = -BD$$

$$r^2 - \frac{(B+2D)\,r}{0{\cdot}429} = -\frac{BD}{0{\cdot}429}$$

A quadratic equation from which the radius r is found,

$$r = \frac{B+2D - \sqrt{B^2+4D^2+2{\cdot}284\,BD}}{0{\cdot}858}$$

EXAMPLES.—When $D=4B$ $r=0{\cdot}114\,D$ when $D=\infty$ $r=\frac{B}{2}$

$D=2B$	$r=0{\cdot}23\,D$	$B=\infty$	$r=D$
$D=B$	$r=0{\cdot}35\,D$		
$D=\frac{1}{2}B$	$r=0{\cdot}54\,D$		
$D=\frac{1}{3}B$	$r=0{\cdot}63\,D$		
$D=\frac{1}{4}B$	$r=0{\cdot}70\,D$		

By describing sections in a rectangle whose breadth equals twice its depth, it will be found that

$$\frac{\text{Area of rectangle}}{\text{Wetted boundary}} = \frac{2\,D_2}{4D} = 0{\cdot}5\,D$$

$$\frac{\text{Area of semicircle}}{\text{Wetted boundary}} = \frac{\frac{1}{2}\pi D_2}{\pi D} = 0{\cdot}5\,D$$

$$\frac{\text{Area of best section}}{\text{Wetted boundary}} = \frac{2\,D^2 - 0{\cdot}43 \times (0{\cdot}54\,D)_2}{4D - 0{\cdot}86 \times 0{\cdot}54\,D} = 0{\cdot}531\,D$$

showing that when the radius of bilge is 0·54 times the draft of water, there is a gain of about 6 per cent. over the semicircular or rectangular section.

Professor Macquorn Rankine said that he had revised the mathematical investigation in Mr. Napier's Paper, and could corroborate its accuracy. Its practical utility arose from the fact that the whole, or nearly the whole, of the resistance to the motion of a well-shaped ship arose either directly or indirectly from friction. A theory based on that fact had been applied to practice in designing steamships and their engines by Mr. Napier and himself, in December, 1857, and subsequently, and in every instance with success. He had read a paper giving a general account of the theory, and an explanation of the practical formulæ deduced from it, with tables of comparison between their results and those of experiment, to the British Association in 1861. That paper was published entire in the "Civil Engineer and Architect's Journal" for October of that year, and, in part, in other engineering periodicals also. The theory was connected with some researches on the motion of waves, which were read in abstract to the British Association, and in full to the Royal Society in 1862.

As might be expected in a theory whose practical application was only four years and a half old, various questions still remained to be settled by experiment. A serious obstacle in the way of obtaining exact experimental data as to such questions arose from want of precision in the indicator diagrams of steam engines, especially in engines of rapid stroke, which was produced partly by the friction of the indicator, but chiefly by the oscillations of its spring. One of the best means of diminishing the extent of these oscillations, and the effect of friction at the same time, was to increase the stiffness of the spring and diminish the mass of the indicator piston. He had seen at the International Exhibition an indicator (that of Mr. Richards) in which that principle had been adopted, and, so far as he could judge from having seen it in action two or three times, with very good results in point of precision.

A comparison of the diagrams given by a very accurate indicator applied to the engines of such vessels as the *Admiral*, the *Athanasian*, the *Lancefield*, &c., would settle some very important points regarding the comparative advantages of straight and hollow water lines, &c. Unfortunately, when vessels were engaged in trade it was difficult to find opportunities for making scientific experiments upon them.

The special subject of Mr. Napier's paper, however, was not one of those problematical points; for there could be no doubt that, to diminish a vessel's mean girth, as compared with her sectional area, was a certain means of diminishing resistance; that principle, indeed, had been admitted ever since friction had been recognised as one of the causes of resistance; and Mr. Napier's investigation showed how to carry that sort of diminution as far as possible under the circumstances stated by him, viz: a fixed extreme breadth and draft of water.

The importance of smallness of girth in diminishing resistance was strikingly shown in the case of the well-known match between the yachts *Titania* (now called the *Themis*) and *America*. The *Titania* was the smaller vessel of the two, and had the less capacity for carrying sail; and in order to make her speed equal to that of the *America*, her friction ought to have been less in the same proportion with her capacity for carrying sail. But while the cross-sections of the *America* were nearly triangular, those of the *Titania* were formed by ogee curves of great concavity, producing a comparatively large girth relatively to her capacity; and although the *Titania* had a smaller midship section than the *America*, the quantity called the "augmented surface," upon which the friction depends, was almost exactly equal in the two vessels, and hence the *Titania*, having the less power of carrying sail, was beaten in the race.*

Professor W. Thomson said that he was glad to find that true principles as to the resistance experienced by solids moving through fluids were being applied in practice with such valuable results. The theory which had been hitherto commonly given in treatises on hydrodynamics, was founded on a calculation in which only the front part of the surface of the moving body was taken into account. It was no doubt convenient to neglect the action on the remainder of the surface; for to have included it in the account would have led to the awkward result *of no resistance at all!* Such a theory clearly is wanting in some essential. This we now know to be the reckoning of effects due to the viscosity of the fluid. A probable hypothesis as to the law of viscous force having been adopted, a perfect theory of the motion of a solid through a fluid, at a slow rate, *when no eddies are formed*, had been indicated and worked out in some important cases by Prof. Stokes. It gives a resistance simply proportional to the velocity. But when the motion is so rapid as to give rise to eddies, which it always is in practical cases of water flowing through pipes and of ships, the circumstances become extremely complicated. Prof. Thomson believed that the principles for obtaining practical solutions for the cases of ships were those which Mr. Napier had used in his investigation now before the Society. He concluded by saying that he had had much pleasure recently in testing, by personal experience of a voyage in the *Lancefield*, some of the results of the application of these principles.

Mr. Napier said, that before commencing the construction of the *Admiral*, to which Prof. Rankine has referred, he applied to Profes-

*The *Titania* or *Themis* here referred to is the *Old Titania*. The yacht now called the *Titania* is a vessel of a better model. W. J. M. R.

sors Thomson and Rankine for advice as to the power necessary to propel vessels of any form, as his own experience led him to disbelieve the common theories based on the midship section or displacement. Prof. Thomson stated then what he has now said regarding the friction of water, and Prof. Rankine said, that if the resistance was the same as water in a pipe, the power required to propel his vessel at the given speed would be so many horse. The idea of water in a pipe having any thing to do with the speed of a boat was strange and new to him; nevertheless, the power named was about two-thirds of what he had estimated to be necessary. A few days after making this approximation to the power, he had from Prof. Rankine a formula, to which his notes supplied the data. This formula enabled him to make a vessel whose success was unprecedented. The lines of the vessel were trochoids, with a cylindrical or prismatic middle, and as the breadth was unlimited and the draft of water limited, he made the radius of bilge equal to the draft of water, so as to have the surface a minimum. The *Athanasian* is also a trochoidal vessel, with a very short prismatic middle, and sections giving a minimum of surface. The *Lancefield* is similar to the *Athanasian*, except the bow, which is a wedge, touching the trochoids at their points of contrary flexure. There are other peculiarities, however, in the *Lancefield* to which some of the economical results described by Prof. Thomson may be due.

Discharge Pipes of Fire Engines.

From the London Practical Mechanic's Journal, July, 1863.

SIR:—What is the proper form for the nozzle of the discharge pipe of a fire engine, so that it may project its water to the greatest distance or altitude? Does the contracted vein answer that purpose? Have any experiments of a scientific character been made in proof of this object?—Yours, truly, JOHN CAMERON.

10th June, 1863.

In reference to the preceding inquiry of our correspondent, nothing worthy the title of a special train of experiments has ever, that we are aware of, been made as to the best form for the discharge pipe for fire engines. A sufficient amount of collateral information, both purely scientific and practical, exists, however, to have pretty well decided the form that, upon the whole, best answers all the required conditions. The "hose-pipe," "hand-pipe," "discharge-pipe," or "jet-pipe,"—for by all these names is it indifferently known—must be of such a form that it can be readily handled, and can be effectively employed as an instrument *to direct* at will the issuing stream of water. It is convenient, also, that its length and form be such that it can be maintained stopped by the thumb when requisite, or until the elastic pressure in the air vessel has been accumulated.

As regards the form of the adjutage itself, from which the issuant jet is finally delivered, the most important point is that it shall be such as to deliver a fine, smooth, and perfectly unbroken cylinder of liquid,

for the slightest initial irregularity or break of symmetry tends to make the column of the jet break up into drops and spray sooner than it might otherwise have done.

Whatever be the form or structure of the jet-pipe, it is scarcely necessary to say, that at some certain distance, it *must* always break into spray, dependent upon the diameter and velocity of the jet, the resistance of the air or wind, the direction of throw in relation to the horizon, i. e., the angle of elevation, and the latitude of the place—the latter not being a very material element.

Perfect cylindricity, or rather perfectly smooth and circular section of the conic adjutage, and gradual reduction of area, of cross section, from the leather hose towards the extremity, best insure the unbroken issue of the fluid jet. The old forms of "hand-pipe," from the days of Leupold and the old German "squirting machines," were long cones of brazed sheet copper, with a female screw to take to the hose at one end, and a male one to take different sized brass conical nozzles at the other. The whole length was about six feet, and that of the change nozzles about nine inches. At a later period, these had a male and female screw joint in the middle of the length, by which the hand-pipe could be shortened one-half, and its cross section of issue proportionately enlarged. These hand-pipes answered extremely well. They were liable, however, to three objections. The great length of the cone (nearly six feet) involved a rather serious amount of resistance (whether by friction or otherwise, we need not here inquire) to the work employed at the fire engine. This was such, that we have ourselves more than once seen a copper hand-pipe split right up, at about one-third its length from the hose, by a pressure which the latter stood safely. The long pipe was occasionally found awkward in narrow passages and staircases, &c., where surrounding obstacles prevented the jet being thrown in the desired direction. Lastly, as fire engines often take in and drive through their valves, &c., solid bodies, such as chips of wood, bits of oakum, pebbles, &c., these often stuck fast in the long conical hand-pipe, and were very hard to drive back, from the velocity with which they had been propelled into the pipe, while the sudden stoppage visited a tremendous fluid strain upon the hose and air vessel.

As remedies for all this, the "short hand-pipe" was introduced, we believe, by the late Mr. Braidwood, of the London Fire Brigade—at any rate, we think, not anterior to his time. This consists of a slightly conical copper pipe, with the female screw, as before, at its lower end, equal to the cross section of the hose which it takes on to. The length is only from 2 to 3 feet, varied by different makers a few inches, and the reduction of cross section varies from $\frac{1}{3}$ to $\frac{1}{2}$ that of the hose at the outer end. Here, there is a male screw which receives a short brass adjutage (with change pieces), the length of which is usually from 3 to 4 times the diameter of the lip of the adjutage.

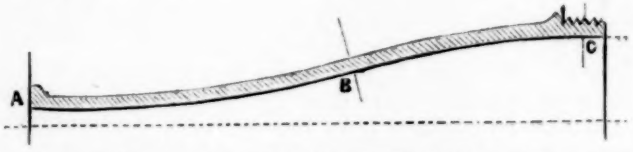
The form interiorly is that of a solid, generated by the revolution on the axis of the jet, of a curve approaching something towards a parabola, which at the circumference of the lip, has a common tan-

gent with the jet column, and parallel to its axis therefore. The other end of the curve meets the cone of the hand-pipe more or less abruptly, thus—

This form of hand-pipe is handy in use, and easily cleared when stopped, and much lighter to handle than the long one, and, indeed, is better in every respect.

We do not hesitate to say, however, that the form of the adjutage at its extremity is bad, and is constructed in defiance of all sound hydraulic principles.

We believe the proper form, and about the proper proportions for the adjutage to be attached to the outer extremity of the conical copper pipe, should be as follows:—The interior form of the adjutage or nozzle should be that of a solid generated by the revolution on the axis of the jet, of two conjunct reversed trochoids, the one having a common tangent with the copper conic frustrum at its junction with it, the other a common tangent with the jet itself, and therefore parallel to its axis. Thus—



The total length from A to C, should, we think, be not less than 10 D, D being the diameter of the adjutage at A, and it is probable that even a greater length would be advantageous with very high issuing velocities. The trochoids, A B . . C B, may be equal in length, but we have some reason to think that the better results would be produced by the inner one, C B, being in length (along the axis) to the outer one in the ratio, of $\frac{2}{5}$ to $\frac{3}{5}$. We know, by actual practice, that this form gives a decided increase of range, with equal power expended, of throwing a given volume of water from the same engine. The jet thrown is also truly smooth and solid.

To determine, however, the very best *proportions* for these adjutages, would still require a considerable and a skilfully conducted train of experimental research. It is one that in these days of steam fire engines we deem well worthy of being pursued by some one or other of the makers of these machines, with the assistance of some competent man of science acquainted with the mechanics of fluids. In conducting such experiments the relative amount of distress upon the engine and hose is one of the most important conditions. As experi-

ments have been hitherto conducted with man-wrought fire-engines, no exact result is possible, indeed, most of the conditions are impossible to be ascertained at all; either they should be made with steam-wrought engines, and the known appliances to ascertain, useful and useless power employed; or if by hand-wrought engines, by the application of the indicator directly to the cylinders of the engine—a thing which, so far as we know, has never been attempted as yet.

EDITOR.

On an Optical Instrument which Indicates the Relative Change of Position of two Objects which are Maintaining Independent Courses. By JAMES M. MENZIES, B.A.

From the Lond. Civ. Eng. and Arch. Journal, March, 1863.

A person on the deck of a vessel at sea can form a tolerably good calculation of the distance of a stationary object by taking two angular observations of its position, and by knowing the distance he sails in the interval between the times of taking the angles. The question is then a case of plane trigonometry, in which the base—which is the distance sailed over—and the two angles at the base are given, to find one or both of the other two sides. The closer this triangle approaches the equilateral form, the more nearly may the calculated distances be expected to approximate to the truth; while on the contrary, the smaller the vertical angle the less likely will the data and the calculations dependent upon them be correct. Trigonometry thus furnishes the means of calculating the distance of an object from the deck of a vessel, provided the object be *stationary*.

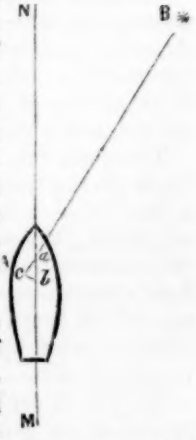
If, however, the object be in motion—if, for example, it be a vessel proceeding on its course—then it is impossible by means of trigonometry to calculate its distance from the deck of a vessel which is itself in motion. An estimate of the distance may be formed by the eye, and in the daytime the estimate may be very accurate, but at night, when nothing is seen of a vessel except its bewildering light, it is extremely difficult to determine either its course or its distance. At present it is found necessary to employ two lights in sailing vessels and three in steamers to ensure their safety; but, notwithstanding this, it is so difficult at times to steer a ship so as to avoid collision, that any improvement upon the usual means of navigation would be a boon to those whose lives are now exposed to peril.

An attempt has been made in the present instance to produce an instrument which shall indicate the relative change of position of two vessels that are in motion; the observations will require to be continued for a longer or shorter time, but it is one which needs little or no skill to make, and it has not to be supplemented by any arithmetical or other calculation whatever. The instrument consists of a lantern-like case, whose form is that of a half or smaller section of a cylinder. The front, top and bottom, consist of thin rigid plates of metal, and the circular boundary is a bent sheet of glass or mica, kept in its position by metal grooves. The interior surface of the

glass or mica is covered with tracing paper, attached to it by means of varnish, and on the exterior surface vertical lines are drawn in transparent colors—the central line being made broader and more defined than the others. In the axis of the cylinder a converging lens is placed, which has a focal length equal to the radius of the cylinder, and the position of the lens is such that it depicts the images of objects in front of it upon the bent sheet of mica behind it. In the instrument exhibited a view is obtained of only such objects as are situated in that portion of the sea which is comprehended within 150° of the horizon circle; but by making the instrument revolve on the cylindrical axis (which can easily be done) a range of the whole horizon can be commanded. The instrument is suspended from gimbals, and in placing it in position on deck, a line joining two opposite points of suspension must be parallel to the ship's keel or course. This adjustment is effected in the same way as that of the steering compasses. When protected with a covering, which is principally made of glass to enable observations to be taken, the instrument is ready for use.

In the instrument the light of a vessel, whose course in relation to that of the one in which the observation is being made is desired to be known, is converged by the lens into a bright illuminated spot on the bent mica. The broad colored lines drawn at the middle of the mica indicates the vessel's own course, and the distance of the illuminated spot from this line represents the angular distance of the observed vessel from the course in which the other is advancing. If the position of the observed vessel be on the right of the other's course, the illuminated spot will be on the *left* of the broad line, and *vice versâ*.

An observation is taken in this manner:—Observe whether the illuminated spot move to the right or left of its first observed position; (1st) if it move *towards* the broad line drawn on the mica, the observed vessel will cross the course of the other before the latter can come up to the point of intersection of the two courses; (2d) if the illuminated spot move *away from* the broad line, the observed vessel is sailing away from the course in which the other is advancing. In neither case can there be collision. But, on the contrary, if the illuminated spot move neither to the right nor left, it follows that the two vessels will reach the point of intersection of their courses at the same moment—in other words, there will be collision.



Thus, let the vessel A be proceeding in the course M N in the direction of N, and let B be the light of another vessel, then the arc *bc*, which the instrument indicates, is the measure of the angle B *a* N, and it is evident that if the illuminated spot *c* move towards *b*, the vessel B will cross the course M N before A reaches the point of intersection of the course; if *c* move away from *b*, the vessel B is moving away from the course M N; but if *c* remain fixed,

then the vessels reach the point of intersection of their courses at the same moment—that is, there will be a collision.

Should the vessels be sailing in the *same* direction, there is one doubtful case. It does not necessarily happen that the fixed position of the illuminated spot will be followed by collision, collision will or will not happen according as the observed vessel is approaching to or receding from the course of the other. Sufficient warning is given of danger, and perhaps it does not greatly detract from the value of an instrument, if in a case of comparatively rare occurrence, it calls for the exercise of caution which is not really needed.

The instrument is offered rather as an optical solution of a problem for which trigonometry proves unavailing, than as a practical help to navigation. Between the theoretical accuracy and the practical utility of an instrument, there is often a wide difference. The chief difficulty in practice appears to be to get an instrument at once *large* enough to make observation with it easy, and *small* enough to render it compact for management on shipboard.

Unbranning of Wheat.

From the Lond. Mechanics' Magazine, December, 1863.

In the report on the alleged grievances of the journeymen bakers, made by Mr. H. Seymour Tremenheere, to the Secretary of State for the Home Department, a process of unbranning wheat is described, which seems likely to exercise an important bearing on the supply of food. Messrs. Hadley, of the City Flour Mills, stated to Mr. Tremenheere as follows:

We have been making experiments for some time on the mode of unbranning wheat, invented by Mr. Bentz about the year 1846, in America, and subsquently patented. The object of this process is to separate the outer cuticle, which is wholly innutritious, from an interior section of the wheat-berry, which contains mostly nitrogenous matter, and which has hitherto been lost as human food.

There are two leading advantages in this process. First, the cleanliness of the flour produced. In grinding by the ordinary process it is impossible to render the flour entirely free from dust and dirt. After putting the wheat through two or three processes of cleaning in the common way, there will still be some dirt remaining in it. All flour always contains more or less of this dust. There is also a portion of the beard of the wheat, a kind of fibrous appendage, which is always ground up with it; no process hitherto known has been able to get rid of it.

By Mr. Bentz's process, as the exterior cuticle is entirely removed previously to grinding, the flour is necessarily perfectly clean, and free both from dust and this fibrous down.

Secondly, by the ordinary mode of grinding, the result obtained is 76 per cent. of flour for human use. By the new process we find, after a series of very careful experiments, extending over several months,

that we obtain about 86 per cent. of the whole berry available to make bread.

The money value of this increase of 10 per cent. is subject to a deduction of about one-half in consideration of the lessened quantity of offal, the value of which we may take at half of that of the flour if used as human food. The offal is used for many purposes, which give it a value larger than would at first sight be conjectured.

In addition to this net increase of 5 per cent. in value of flour available for human food, the flour made by this process, containing all the nitrogenous or nutritious matter existing in the berry hitherto lost, yields at a large increase in the number of loaves per sack. From the trials which we have ourselves made, we are satisfied that that increase may be safely stated at 20 lbs. of bread per sack of flour. This, taking the common average yield of a sack of flour at 90 four-pound loaves, or 360 lbs. of bread, amounts to an increase of upwards of 5 per cent. on the bread (18 lbs. would be exactly 5 per cent.)

The aggregate gain in flour and bread may, therefore, safely be stated at 10 per cent.

There is also another source of gain in a national point of view, in the increased nutritive value of the whole mass of the flour made by this process.

Dr. Dauglish, whose paper descriptive of his process of making aërated bread was read before the Society of Arts, in reference to the unbranning, states as follows:

The invention was brought under the notice of the French Emperor, who caused some experiments to be made in one of the French bakeries, to test its value. The experiments were perfectly satisfactory, so far as the making of the extra quantity of fine flour was concerned; but when this flour was subjected to the ordinary process of fermentation, and made into bread, much to the astonishment of the parties conducting the experiments, and of the inventor himself, the bread was brown instead of white. The consequence, of course, has been, that the invention has never been brought into practical operation. But, about four years ago, a French chemist, M. Mége Mouriès, directed his attention to the subject of utilizing for the purpose of white bread-making, the nutritious substances ordinarily thrown away with the bran, and the results of his inquiries were communicated in a memoir to the Academy of Sciences, on June 9, 1856, and have since been reported on by MM. Dumas, Pelouze, Payen, Peligot, and Chevruel.

These results explain most satisfactorily the cause of failure of the flour prepared by the American method to make white bread.

Before the publication of M. Mouriès' researches, the nutritious substance attached to the bran was considered by chemists to be a portion of the gluten of the grain, but it now proves not to be gluten at all, but chiefly a new nitrogenous body analogous to gluten, which the discoverer has named "cerealine," with a portion of another well known nitrogenous body—"vegetable caseine."

Among the properties of this body, cerealine, M. Mouriès gives the following:—

It is soluble in water, and insoluble in alcohol. It acts as a ferment on starch, dextrine, glucose, or grape sugar. It alters gluten extremely, and gives to the altered matter a brown color. Its peculiar action, when brought into contact, in the process of fermentation, with the ordinary constituents of fine white flour, is the true cause of the dark-brown color imparted to the bread made from flour in which the cerealine was retained.

M. Mouriès, having satisfied himself as to the properties of cerealine, adopted a method by which its peculiar action was neutralized, and then made bread by the ordinary process of fermentation, in which the whole of the bran contained in the internal coat of the grain was allowed to remain. The result was a loaf having merely an orange color, but none of that dark-brown color which always results when the bran contained in the internal coat of the grain is used in bread made by the ordinary method.

In like manner, by my process, in which the fermentative changes are never allowed to take place, bread made from wheaten meal, from which only the coarse bran has been separated, is so free from the dark-brown color that it is difficult to persuade people that it is made from wheaten meal at all.—*Chemical News.*

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, July 16, 1863.

John C. Cresson, President, in the Chair.

John Agnew, Vice President.

Alexander Stewart, Recording Secretary pro tem.

The minutes of the last meeting were read and approved.

A letter was read from T. Oldham, Esq., superintendent of the Geological Survey of India.

Donations to the Library were received from the Royal Astronomical Society, and the Society of Arts, London; the Canadian Institution, Toronto, Canada; T. Oldham, Esq., superintendent of the Geological Survey of India, Calcutta, India; the Société Industrielle de Mulhouse, France; the Academy of Science, St. Louis, Missouri; Charles Whittlesey, Esq., Washington, D. C.; the Mercantile Library Association, City of New York; and John L. Newbold, Esq., Philadelphia.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

The Treasurer's statement of the receipts and payments for the month of June was read.

The Board of Managers and Standing Committees reported their minutes.

Candidate for membership in the Institute (1) was proposed, and the candidates (5) proposed at the last meeting were duly elected.

Mr. Howson of the Committee on Meetings, exhibited some speci-

mens of Cartridges and Cartridge Cases made at the arsenals of Richmond, Va., and Augusta, Ga.

Mr. H. remarked that he picked up the specimens on the ground near Boonsboro', at the foot of the South Mountains where the important cavalry fight took place last week between General Buford's cavalry and the rebels. The specimens were obtained at a point where the rebels had made a firm stand, as related to the exhibitor by a captain in the regular army, who took part in the engagement.

Many cartridges containing spherical balls and intended for smooth bore guns were here found packed in wooden cases with the labels of the manufacturers at Richmond and Augusta, also several cartridges with minnie balls. A number of metallic cartridges also, contained in wooden cases and similar to the specimen produced, were found at this point, which is somewhat remarkable, as the rebels were not supposed to be in possession of ammunition of this class.

Mr. H. also exhibited a map drawn to a large scale and exhibiting the ground over which the recent campaign was conducted in Maryland and Pennsylvania.

A Churn the invention of G. L. Witsel, of this city, was also exhibited. It consists of a simple box with a vibrating dasher and a centre perforated partition through which as well as through the dasher the cream is forced backwards and forwards. Butter is produced in a much less time by this churn than by the ordinary barrel churn.

Mr. Howson exhibited a Calfskin tanned in accordance with the patent granted to H. G. Johnson and the improvement of S. Dunseith of this city. The principle ingredient used in this process of tanning, is a decoction of the plant known as the wild chamomile. An ordinary calfskin can be tanned by this process in fourteen days, and a cowhide in twenty-one days.

Mr. Lightfoot exhibited some very superior specimens of Leather curried or dubbed by his new composition, which consists of petroleum and tallow, and which is much cheaper than the ordinary dubbing.

Mr. F. C. Fowler exhibited Mr. Pain's patent Carriage Jack, an instrument which has recently become very popular in this city.

Mr. Howson exhibited a specimen of Mr. George Snyder's patent Razor Strop and hone combined. The instrument being especially adapted for army and hospital uses.

A Coal Oil Lamp invented and patented by Lewis Bader of this city, was also exhibited. It produces a brilliant flame without the aid of a chimney.

Mr. W. Jones exhibited some specimens of Austrian Gun Metal, a description of which was given in the May number of the *Journal of the Franklin Institute*, and of which a further description will be given in the next number of the Journal.